This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

ELECTRIC LIGHTING.

ELECTRIC LI

TRANSLATED FROM THE FRENCH OF

LE COMTE TH. DU MONC

BY

ROBERT ROUTLEDGE, B.SC. (LON

Author of

"DISCOVERIES AND INVENTIONS OF THE NINETEENTH

"A POPULAR HISTORY OF SCIENCE," ETC.

WITH SEVENTY-SIX ILLUSTRATIONS

SECOND EDITION

LONDON
GEORGE ROUTLEDGE AND S
BROADWAY, LUDGATE HILL
NEW YORK: 9 LAFAYETTE PLACE
1883

D82

BY THE SAME AUTHOR.
In Crown 8vo, cloth, 10s. 6d.
DISCOVERIES AND INVENTIONS
OF THE
NINETEENTH CENTURY.
BY ROBERT ROUTLEDGE, B.SC. (LOND.), F.C.S.
With 400 Illustrations, Portraits, &c.

J. E. F.

TRANSLATOR'S PREF

THE book in the reader's hand is a tra second edition of the Comte du Mon *age Électrique,*" published at Paris, by the M in 1880. Though the original work is one tended for popular use, it leaves nothing t the score of scientific treatment. An abl handling of the subject that occupies the is, indeed, precisely what would be expecte are acquainted with the very eminent scie the Comte du Moncel as an investigator a While the general reader will find in the fo that he can possibly require to know about and find it, too, laid before him in full an tions, divested of all perplexing technicalit that the book may prove of more extende utility, by supplying serviceable guidance creasing number of persons who are called how far this latest gift of science can be purposes. Such are more especially eng managers of industrial and commercial esta kinds, municipal officers, members of local of railway and steamship companies, lessees tors of museums, and of picture galleries, classes of persons too numerous to mentio feature of the present work—because it is a common, either in scientific or in popula

46155 4

from the first page to the last, the practical point of view is never for an instant abandoned.

No special knowledge of electrical science is needed for the intelligent perusal of this work; nevertheless, a reader altogether new to the subject would do well to acquire clear ideas of a few elementary facts. Almost any of the cheap manuals which now abound would suffice to convey all the information required; but it could not, perhaps, be attained more pleasantly and profitably than by a reference to Professor Tyndall's "Notes of a Course of Seven Lectures on Electrical Phenomena and Theories," which may be had for a few pence.

The present translation contains all the author's notes, references, and appendices. To these, two other appendices are now added by the translator. The first gives the English equivalents of the French weights, measures, etc., which, on account of their now almost universal employment for scientific purposes, it has been deemed expedient to retain in the text. The second is a brief notice of some forms of incandescent lamps, and of another recent invention, which have come into prominence since the publication of the original work. Several lamps of this kind may now be said to have proved completely successful in practice, and the forms described in the appendix are those which have attracted the largest share of public attention, as offering the simplest and most effective solution of nearly all the difficulties that have hitherto attended the application of electric lighting to domestic and certain other purposes.

The translator, having been unable to refer to some of the English and American newspapers, journals, and reports quoted by the author, has usually contented himself with a faithful rendering of the French version; but it is not, of course, to be expected that the *ipsissima verba* of the

CONTENTS.

PART I.—GENERAL CONSIDERATIONS.

PAGE
HISTORICAL SKETCH 1
IMPORTANT DEFINITIONS 4
Electric current 4
Electro-motive force 5
Tension of a current 5
Electrical potential 6
Electrical intensity 6
Electrical resistance 7
Electrical conductivity 8
Electrodes 9
Polarization 9
Electric Units 10
WHAT THE ELECTRIC LIGHT IS 12
THE VOLTAIC ARC 16

PART II.—GENERATORS OF ELECTRIC LIGHT.

VOLTAIC GENERATORS 25
Grove's and Bunsen's batteries 25

PAGE
Voltaic constants 29
Grouping of elements for tension or for quantity ... 30
Conditions for maximum current 32
Derived circuits 32
Mode of Propagation of Electricity 35

THERMO-ELECTRIC GENERATORS 38
History 38
Clamond's piles 39

MAGNETO-ELECTRIC GENERATORS 46
Induced current 46
History of the Question 46

THE DIFFERENT MODES OF GENERATING INDUCED CURRENTS, AND THE LAWS WHICH GOVERN THEM... 52
Laws of Induced Currents... 54

VARIOUS MAGNETO-ELECTRIC GENERATORS OF ELECTRIC LIGHT... 61
The Alliance Machine 62
Wilde's Machine 68
Ladd's Machine 71
Gramme's Machine 74
Siemens' Machine 82
De Méritens' Machine 85
Wallace Farmer's Machine... 90
Brush's Machine 92
Bürgin's Machine 95
Trouvé's Machine 97
Lontin's Machine 98

MACHINES WITH ALTERNATE REVERSIONS OF THE CURRENTS, ESPECIALLY APPLICABLE TO THE DIVISION OF THE ELECTRIC LIGHT 100

Lontin's System ... ...
Gramme's System ...
Siemens' System... ...
Jablochkoff's System ...
COMPARATIVE EXPERIMENTS ON
DUCED BY THE DIFFERE
MACHINES ... ...
EFFECTS OF THE RESISTANCE OF
RESULTS PRODUCED BY COUPLING
TABLE OF THE AMERICAN EXPERI
COMPARATIVE TABLE OF THE ENGL
TABLE OF NEW EXPERIMENTS (SH
APPARATUS FOR EVOLVING THE E
Light produced between ca
Jacquelain's Method ... ..
Carré's Method ... .
Gauduin's System ... ..
Effects produced by the add
Salts to the Carbons p
Electric Light ... ...
Metallized Carbons ... ...
Effect of heat on the con
carbons ... ...
Light produced by means o
indifferent conductivity
Jablochkoff's System ... ...
Lodyguine and Kosloff's System
Edison's System ... ...
Systems of É. Reynier, Werderm
Light produced by means
action ... ...

PART III.—ELECTRIC LAMPS.

PAGE
VOLTAIC ARC LAMPS 152
Foucault and Duboscq's Lamps 154
Serrin's Lamp 161
Siemens' Lamp 165
Lontin's Lamp 169
De Mersanne's Lamp 170
Bürgin's Lamp 172
Gaiffe's Lamp 174
Carré's Lamp 177
Brush's Lamp 178
Jaspar's Lamp 180
Rapieff's Lamp 181
Baro's Lamp 185
Wallace Farmer's Lamp 186
Houston and Thompson's Lamp 186
Molera and Cebrian's Lamp 187
Lamps of various kinds 188
Regulators with hydrostatic actions 190

INCANDESCENT LAMPS 195
King's and Lodyguine's Lamps 195
Konn's Lamp 196
Bouliguine's Lamp 198
Sawyer-Man's Lamp 199
E. Reynier's Lamp 199
Werdermann's Lamp 205
Trouvé's form of Reynier's Lamp 209
Ducretet's form of Reynier's Lamp 211
Tommasi's Lamp 212

Edison's Lamp
Automatic ligh
ELECTRIC CANDLES
Condensers
Other Systems
Jamin's Candle
Solignіac's Candle
Lavaud de l'Estra

PART IV.—COST

Cost of the Electri
Cost of the Electr
Machines ...

PART V.—APPLICATIO
LI

Application to Public Il
Application to the Ill
houses ... ...
Application to the Lightin
Application to Nautical Si
Application to the Arts of
Lighting of Railway Train
Application of the Electr
Lighting of the Drifts
Application to Lighting R
Workshops, &c.... ...

PAGE
Application of the Electric Light to Fishing 281
Application to Submarine Working 283
Applications to the Projections on a Screen of Optical Experiments, Photographic Transparencies, &c. 283
Public Trials of the Electric Light 289
Application of the Electric Light to Theatrical Representations 290

PART VI.—CONCLUSION.

REVIEW OF FOREGOING STATEMENTS 293

NOTES AND APPENDICES.

NOTE A.—ON THE INDUCTIVE ACTIONS IN THE NEW DYNAMO-ELECTRIC MACHINES 296
NOTE B.—ON THE DUTY OF GRAMME MACHINES ACCORDING TO THE RESISTANCE OF THE EXTERNAL CIRCUIT 302
Internal Resistance of the Machine 304
Electro-motive Force 304
Intensity of the Current 304
Work transformed into Electricity 305
Utilizable Work in the External Circuit 306
Duty 306
Tension and Quantity Machines 308
Elements of the working of Gramme Machines ... 308

NOTE C.—THE CRITERIA OF THE ELECTRIC LIGHT
NOTE D.—ON A NEW ARRANGEMENT OF THE WERDE
MANN LAMP ... ...
NOTE E.—ON EDISON'S NEW DISCOVERY ... ...

TRANSLATOR'S APPENDIX.—No. 1.

ENGLISH EQUIVALENTS OF THE FRENCH DENOMIN
TIONS USED IN THIS VOLUME ... ...

TRANSLATOR'S APPENDIX.—No. 2.

RECENT INVENTIONS ... ...
Incandescent Lamps ... ...
Swan's Lamp ... ...
Maxim's Lamp ... ...
Edison's Lamp and Fox-Lane's Lamp ...
The Faure Secondary Battery ... ...

ELECTRIC LIG

PART I.—GENERAL CONSIDE

HISTORICAL SKETCH.

THE need of illumination in the absence of
felt by man in the earliest ages of the wo
artificial production of light by fire, which he was
cover, is even one of the great characteristics by
distinguished from other animals. At first he ha
merely pieces of burning wood, fragments of dry
branches of resinous trees, of which he made tor
he would notice the combustible and illuminating
of certain oily liquids; and we see that the He
Egyptians, and the nations of India and Upper
acquainted with the use of lamps at the most remote
But these lamps, even among the Romans, had sm
such as would not be used at the present day by
rudest peasants. The tallow candles invented in E
the twelfth century, and not introduced into Franc
reign of Charles V., were in the middle ages cons
great advance in illumination, and lamps for ligh

date from but the seventeenth century (1667). It was only in the middle of the succeeding century that the famous *réverbères* (street lamps with reflectors) were invented, which in our youth we still saw hung in the middle of the streets in several towns. At the present time we have a great contempt for these means of illumination, and yet when Quinquet in 1785 invented the class of lamp that bears his name, it was supposed that he had made a magnificent discovery;* and I yet remember the enthusiasm which hailed Carcel's invention of the lamp with clockwork. It was, however, only at the period of the discovery by Lebon of the illuminating properties of gas, in 1801, that the revolutionary era of public illumination commenced; but although from the first the immense advantages of this method of illumination could be proved, the determination to adopt it required a long time. It was in England that the first applications of this system to the lighting of streets were made, and although the invention was entirely a French one, people did not bethink themselves of using it in Paris until 1818, under the administration of De Chabrol. The producers of lamp oil were at this time struck with dismay, for in this discovery they saw the ruin of their industry. But they soon found that, contrary to their expectation, the consumption of lamp oil increased with the development of gas illumination. It could not, indeed, have been otherwise, for gas illumination, by accustoming people to a brighter light, was bound to cause an increase in the number of lamps used for private illumination, and an improvement in the construction of the lamps themselves, so that for the same object they might burn a larger quantity of oil.

This retrospective glance shows us that at the present time the consequences which may result from the development of electric lighting are erroneously exaggerated. If this means of illumination should come to be produced under thoroughly practical conditions, still many years will be r it is generally adopted, and even then it ca applied; but as people become accustomed t light which makes the gas-jets appear as dull made the street oil lamps, it will be found crease the number of gas-burners in places obliged to be used, and it may be that th will even exceed that of the present day. W seen that the electric lighting of the Avenue stimulated the improvement of the gas-lights 4 *Septembre*, and there is no doubt that peopl not rest satisfied with the present illumination.

---

* It appears that Argant was the inventor, and that Quinquet merely improved the lamp by adapting to it the glass tube which acts as a chimney.

Although the discovery of the immense lumi the electrical discharge taken between carbon not new, it was only in 1842 that experiments w sufficient importance to enable the possibility of ment as a means of public illumination to be fore results obtained at that period by Deleuil and Arc their experiments, carried out on the *Quai Conti* an *Place de la Concorde*, astonished all who witnessed the people already asked themselves whether by operating very large scale it might not be possible to produce artif suns, each capable of illuminating a whole quarter of city. But at that period the supply of electricity necessar for the production of the light involved considerable expense the means of rendering the light uniform were very primitive and competent persons had little faith in the possibility applying it to public illumination. In 1857, however, th magneto-electric machines of the *Alliance* Company, orig nally constructed for a purpose quite different from the ele tric light, soon showed, after numerous improvements ha been effected in it by J. Van Malderen, that this light cou be produced under favourable conditions, and also that und such conditions it was, light for light, cheaper than ga Thereupon the idea of applying it to public illumination reverted to; but the difficulty of dividing it and distribu

er several places, the superintendence which it was ne-
ary to bestow on the working of the electric lamps, and
irregularity of their action, discouraged even the most
guine. It is only in quite recent times—after fresh im-
vements in the electric machines, in the carbons of the
nps, in the lamps themselves, and particularly after the
eresting experiments made by the Jablochkoff Company
lighting streets and private establishments—that the ques-
on has again come to the front, but this time under infinitely
ore favourable conditions, which promise its speedy solu-
on. To judge by the flutter in gas companies' stock in
ngland, as well as in France and America, we may conclude
at the matter has become serious, and that we shall pro-
ably in a few years hence witness the—at least partial—
ansformation of public illumination.

IMPORTANT DEFINITIONS.

Before entering into any detail on matters relating to the electric light, it appears to me indispensable to clearly lay down the meaning that must be attached to certain words which we shall often have occasion to use, and which, though perfectly precise and definite in their signification, are not always rightly understood, and hence much deplorable confusion often arises.

In the first place an *electric current* is, in fact, nothing in itself but a dynamical action or motion resulting from the destruction of electrical equilibrium in a conducting system, its effect being a tendency to the re-establishment of the disturbed equilibrium through the medium of another conductor. Consequently, if the cause which has produced this destruction of equilibrium is but momentary, the curr for an instant; it is in that case a *discharge*. Bu persists, the current becomes continuous, and pared to a stream supplied by a spring: this is *current* properly so called.

As the effect of a current is to re-establish the which has been disturbed at some point of a cond tem, it naturally follows that the two free extremit conducting system must be united in order that th may show itself; the system then forms a true *circu* more or less resembles the circle, but which is always in the same way; that is to say, the current having a direction at the point where the disengagement of ele or destruction of the electrical equilibrium occurs, have the contrary direction in the opposite part o circuit.

That which produces the destruction of equilibrium spoken of is named the *electro-motive force*. The ext partisans of the electro-chemical theory do indeed r this expression, because it is associated with Volta's th which they will not accept; but whatever theory ma adopted, this expression is entirely suitable; for since electric current is a phenomenon of motion, and e motion is the effect of a force, it is quite certain that in e circuit traversed by a current there is a force put in act and this force may therefore be termed the *electro-mo force*.

The *tension* of a current, which is now often confoun with the *potential*, is the property of the electric fluid, wh in a manner gives the impulse to the electrical moveme and which outwardly manifests itself by a tendency to on the adjoining objects, and to produce the effects pecul to static electricity. It is the quantity of electricity ke free at the poles of a battery when these are not connecte and which escapes recomposition during the time that th disengagement of electricity continues.

The *potential* of a source of electricity* is related to the tension; but, being applied to the electrical actions themselves, it may represent the tension under more defined conditions, which admit of numerical expression. It may be roughly defined by saying that it is to electricity what temperature is to heat; it is, in a manner, the *quality* of the electricity, and this properly has relation to the *quantity*. The notion of the potential of an electrified conductor necessarily originated from the study of the conditions of electrical equilibrium, according to the laws discovered by Coulomb. For the existence of these conditions of equilibrium it is necessary that the resultant of the attractive and repulsive forces acting upon an interior point should be *nil;* but it does not therefore follow that the action of the electricity spread over the surface of a conductor should also be *nil;* and it is the mathematical expression representing this action with the zero resultant that is called the electric *potential.*

The electrical *intensity* represents the magnitude of the effect produced by the electro-motive force, that is to say, the force of the current; it is, therefore, always in proportion to the *quantity of electricity* circulating in the conductor, and *it must depend upon the amounts jointly of the electro-motive force and of the resistance offered by the conductor to the motion of the fluids.* Ohm has shown that its value may be expressed by the ratio of the electro-motive force to the resistance of the conductor, and this supposes that it is *directly proportional to the electro-motive force, and inversely proportional to the resistance.* Again, Joule has shown that the heat developed by an electric current is *proportional to the time, to the resistance of the circuit, and to the square of the quantity of electricity which passes through the circuit in a given time.*

---

* Abria, in an interesting paper on the Elementary Theory of Potential, thus defines it:—"Let us call the *Potential* of an electrified body the indication of a torsion balance, in which the movable ball and the fixed ball are two small equal spheres, which, being in contact, have been connected with the body by a long and thin wire."

IMPORTANT DE

The *resistance* of a conductor r
the obstacles offered by its mat
passage of the fluid : *it is the invers*
resistance depends, therefore, on th
and on its dimensions. Ohm has s
is, for the same kind of conductors,
the section of the conductor, that is to
tained by cutting it perpendicularly tc
found that the resistance was *propor*
inversely proportional to the conductivi
indefinite mass like the earth, the res
pendent of the distance between the points
municates with that mass, and depenc
conductivity and on the surface of the p
the communication ; it may therefore b
versely proportional to the square root of t

As a circuit is usually composed of sev
of conductors, which therefore offer differ
the same dimensions, it becomes importan
mate the *total resistance*, to reduce them al
and the same unit of resistance,* and when
resistance of the circuit is termed the *reduced*
laws established by Ohm relate only to reduc
It ought always to be borne in mind that ho
may be the several parts of a circuit, *the elect*
the current which traverses it is the same at ever
each of its parts the tensions are different.†

---

* This unit of resistance has long been discussed, and at
electricians are still at variance as regards *the one that shou*
in general, however, the British Association *unit is employe*
name of Ohm is given. This unit *represents about 100 metr*
wire of 4 millimetres diameter. *We shall refer to these units*

† According to the English formula of Latimer Clark, *the foll*
values of the resistances of the most *commonly used metals, t*
length and 1 millimetre of diameter :—

	Resistance in Ohms.	Co I
Annealed Silver	0·01937	
Drawn Silver	0·02103	1

The resistance of metals increases, however, with the temperature, while on the other hand that of liquids and gases decreases. The co-efficients of correction which must be applied to the figures we give in the table below in order to obtain the true value for a given temperature, may be seen in my *Exposé des applications de l'électricité, tome I.*, pp. 37 *et* 453.

The *conductivity* of a body is its property of transmitting an electric current more or less easily. Properly speaking, all the substances of nature are conductors, but in very different degrees and under very different conditions. Metals are the best conductors. Resins, and other substances like India-rubber, gutta-percha, glass, &c., have less conducting power. Liquids and gases are also conductors, but under certain conditions.

The conductivity of bodies may be considered from several points of view. When it allows the electricity to penetrate the whole mass of a body without further action, and to be propagated within it like heat, it takes the name of *conductivity proper.* When, on the contrary, it results only from the effects of successive chemical decompositions and

	Resistance in Ohms.	Conducting Power.
Annealed Copper	0·02057	—
Drawn Copper	0·02104	99·55
Annealed Gold	0·02650	—
Drawn Gold	0·02697	77·96
Annealed Aluminium	0·03751	—
Compressed Zinc	0·07244	29·02
Annealed Platinum	0·11660	—
,, Iron	0·12510	16·81
,, Nickel	0·16040	13·11
Compressed Tin	0·17010	12·36
,, Lead	0·25270	8·32
,, Antimony	0·45710	4·62
,, Bismuth	1·68900	1·24
Liquid Mercury	1·27000	—
Alloy of Platinum and Silver	0·31400	—
German Silver	0·26950	—
Alloy of Silver and Gold	0·13990	—

recompositions, as in the case of l
lytic conductivity. Finally, when it
a preventive action of condensatio
the badly conducting bodies callec
name of *electro-tonic conductivity.*
which produces the effects of electro-
marine cables.

The majority of non-metallic substa
woods, the human body, tissues, &c.,
by reason of their electrolytic conducti
ance depends, therefore, on their greate
power. Most metallic minerals, howeve
of conductivity a very marked conductivi

Finally, to finish these definitions, we
the word *electrodes* is understood the me
are plunged into an imperfectly conducting
to electrify it intimately, and over a surface
for it to acquire a certain amount of conduct
and copper plates of a battery constitute ele
carbon pencils of an electric lamp are likewise
of the luminous arc between them.

Electrodes may also be used not only to
electricity to a badly conducting medium, but a
from it its polarity when it has by any circumsta
charged. In all cases there results from this
electric communication a particular reaction, whi
polarization, and which, being produced in a direc
site to that of the original electric action, disturb
ration of the currents. This action is tolerably si
liquids, but it is very complicated with minerals, a
rise to peculiar and curious effects, which I have st
detail,* but as these have nothing to do with electr
ing they must here be passed over in silence.

Most frequently polarization effects arise from elec actions, that is to say, from deposits chemically produced on the electrodes, and reacting in their turn on the electrified medium. These deposits tend to produce an electrical action in the direction inverse to that of the current; but sometimes they proceed from an electro-static polarity communicated to the medium. A polarization of this kind is often produced in the voltaic arc.

---

* See the author's *Recherches sur la conductibilité électrique d*
mediocrement conducteurs.

We must also give some explanation of the word *condensation*, which we shall have occasion to apply more than once. What is so called is the accumulation of charge obtained by the inductive action which an electric charge produces on a second conductor of large surface insulated from the electrified one. In this action charges of opposite electricities are retained by their mutual attraction, so that they can be accumulated in quantities proportional to the extent of the condensing surface. Under these conditions a slight leakage of charge takes place by electrotonic conductivity, and as the condensing plates then constitute true electrodes, the resistance of the *insulator* or *dielectric* interposed between the two plates or *armatures is inversely proportional to the surface of these plates;* or, what comes to the same thing, if it be the effect on a submerged cable that is considered, *inversely proportional to the length of the cable.*

Electric Units.—In order to find the values of the electro-motive force, and of the resistance of a battery, as well as the values of the other elements acting in an electric circuit, it has been necessary to fix upon some units of electric measurement; and although scientific men are not yet of one accord as to the units which should be adopted, the tendency is to accept the "rational units" that, after long investigations, were fixed upon by the British Association.* These units have received different names, which keep in remembrance the physicists who have in the highest

---

* See the Report of the British Association for 1873, page 222.—(Tr.)

degree contributed to the progress of the science
Thus the unit of resistance has been called th
unit of electric-motive force, the *Volt;* the unit
of current, the *Weber;* the unit of electro-static
Farad. The multiples and sub-multiples of the
designated by terms analagous to those of our metr
but under certain other conditions adapted to the us
made of them in their electrical applications. T
are *mega* and *micro,* which respectively express a
units and the millionth part of a unit; thus a
ohms is called a *megohm,* and the millionth part o
a *microhm.* The most generally used, however, of
multiples and sub-multiples are the *megohm* and th
farad.

We must now learn what these units represent.

The *ohm* practically represents the resistance of a c
of pure mercury 1 square millimetre in section, and
metre long, at the temperature of 0° Centigrade.* T
about the resistance of an iron telegraph wire 4 millim
in diameter and 100 metres long.

The *volt* represents nearly the electro-motive force
Daniell's cell, with sulphate of copper and water slig
acidulated, for if this be expressed by 1, the volt will
represented by 0·9268.

The *weber* represents the volt divided by the ohm.

The *farad* represents the capacity of an electric conden
placed under such conditions that the quantity of electric
carried by a volt through the resistance of one ohm wou
charge it to the tension of a volt. This kind of unit is lit
used except in the study of submarine cables. All
calculations relating to these units will be found in my Exp
des applications de l'électricité, tome I., p. 432.

Measuring instruments graduated to these units can now
had at Gaiffe the Paris instrument maker's, *Rue Saint A*

---

* See the Translator's Appendix No. 1.—(Tr).

des Arts, 40. These apparatus consist in the more or less complete action of resistance coils arranged like a set of weights, and in rheometres graduated in ohms and volts; so that by a simple reading, without calculation, the electro-motive force of a battery, its resistance, and that of the external circuit can be ascertained. The indications are not perhaps rigorously exact, but they are quite sufficient for the ordinary applications that have to be made of electric currents.

WHAT THE ELECTRIC LIGHT IS.

An artificial light is usually the result of a combustion, and we rarely think of a luminous effect without the intervention of a combustible substance. With the electric light, however, this is not the case, for it can be displayed in a vacuum, in water, and in gases incapable of supporting combustion. Whence arises this difference? From the fact that in one case the heat (which always accompanies the production of light), by effecting the decomposition of the combustible substance, gives rise to a disengagement of its constituent hydrogen gas that feeds the flame; while in the other case, the luminous effect is the result of a mere transformation of the physical forces. This transformation shows itself when the conditions of the passage of the electricity are such that, the free development of the electric action being impeded, an abrupt elevation of temperature takes place at one point in the circuit, and there manifests itself by incandescence without any combustion being required for the production of the incandescent effect. This phenomenon follows from the law which requires that, whatever may be the nature of the parts of a circuit, every

part must be traversed by the same quantity of
the same time.

To obtain, therefore, a very marked calorific
have only to cause the electric discharge to pass
medium of insufficient conductivity, and this me
be formed either of a good conductor made very sl
of a gaseous conductor; but the luminous effect i
in proportion to the readiness with which the co
becomes incandescent. If it is a solid, infusible and
conducting substances may be used, such as platinum
especially carbon, provided they have a length and thic
proportional to the electrical intensity of the current.
shall have occasion further on to study some electrical la
based on this principle. When, on the other hand,
intermediate conductor is gaseous, the electrodes or so
rods conveying the current to it should be such that, wh
making it capable of conducting the discharge by the elev
tion of temperature they communicate to it, they may als
be able to carry into the midst of this aëriform medium
vast quantity of extremely minute material particles, for th
medium derives its luminosity from the glow of red-whit
heat communicated to these particles. It is known, indeed
that the flame of hydrogen gas, which is of itself not lumi
nous, becomes so when spongy platinum is placed in it, o
when the gas is charged with carbon.

These considerations have shown that carbon should be
employed as the means for producing the electric light
This substance is a sufficiently good conductor of electricity
it is easily disintegrated, readily ignited, and being itsel
combustible, adds the luminous effect of combustion to th
brightness of the electric light properly so called. Dav
made the first experiments in 1813 on this method of pr
ducing the voltaic arc, and we shall presently see how thi
discovery was completed by Foucault, who substituted reto
carbon for wood charcoal.

The electric light may also be obtained by means of soli badly-conducting bodies rendered incandescent, and we shall have occasion to speak of a system of illumination of this kind, devised by Jablochkoff, who makes use of thin plates of kaolin. But in order to obtain these various results a source of electricity must be available, which not only supplies sufficient electricity to produce energetic calorific actions, but possesses a tension sufficiently powerful to overcome the resistances offered by the intermediate bodies that are to develop the luminous effects; and besides this the source of electricity must be suitable to the conditions of the experiment. It is obvious that if the gaseous interval interposed between the conductors of the discharge or current is considerable, it will be necessary for the generator of the electricity to possess tension especially, whilst to produce a powerful effect between two rather large carbons, separated by a narrow interval of air, quantity will especially be needed, since the calorific effects required to make the carbons incandescent are in proportion to the quantity of electricity produced by the generator.

These two different effects of electric generators may be readily explained by the way in which they operate in setting up the action. If the generator has a very great tension, such as occurs with Holtz's machine and the induction machines, the discharge may take place directly between the electrodes, which in a manner serve to determine it, leaping from one to the other; but as the enormous resistance presented by this gaseous interval very much diminishes the electric intensity, the light so produced is very feeble, and it can be increased only by decreasing the resistance of the gaseous medium, which may be done by rarefying it. The discharge then spreads itself in the vacuous vessel, and if the quantity of electricity be increased by means of a condenser a light of some intensity may be obtained. But this intensity will be considerable only when the discharge carries with it those material particles heated to reddish-whiteness, which, as we have already stated, constitute the whole brilliancy of the electric light. If, instead of employing a g high tension, a generator of electricity *in quantity* is as a battery, especially the battery with acids, the different: the discharge cannot spontaneously be between the opposed electrodes if these be sepa even an extremely small interval. In this case cessary to bring the electrodes into contact, so as to a calorific effect, and since the surrounding gases made conductors by the heat, the electrodes may aft be separated from each other and the discharge be to take place through the gaseous medium, but no more than a very small separation of the electrodes.

It must not be supposed that any one source of elect is especially suitable for producing the electric light: w ever the source may be, it can always be arranged so supply the desired effect. For instance, a battery is cap of giving tension effects if a large number of well insul cells joined by their opposite poles are employed. Gas has succeeded in obtaining sparks with a battery of 3, small cells containing water only, each cell insulated by g supports; and Warren de la Rue has obtained still m important results with chloride of silver batteries. In anot direction, Gaston Planté, with his polarization batteries his rheostatic machine, has succeeded in producing by taic discharges sparks of 4 centimetres in length. By a verse method the *intensity* of a generator can be increa at the expense of its tension, by condensing its charges, by arranging for quantity the elements which co-operate the production of the electricity. Thus, an induction m chine is able to give effects of quantity, if thick wire is us for the induced coil, and if the different coils brought in action are so connected that the induced currents, instea of passing from one coil to another, shall issue simultan ously from each individual coil, and all traverse the same co ductor at once. In this case, as in the former, the pr ponderance of intensity over tension may be varied at wi by grouping the elements *in series*, that is to say, in such a way as to collect for tension a greater or less number of generating groups whose elements are themselves connected for quantity. But farther on we shall have occasion to recur to this important question; here we shall merely add that among the different generators there are some more advantageous than others for the electric light, as regards the energy of their action, as well as the expense attending them, and that the proper choice of a generator is one of the most important questions to be taken into consideration in connection with the electric light. Thus, among batteries, Grove's and Bunsen's are those which always yield the most advantageous results; and among machines the magneto-electric induction machines are those which must be used. Nevertheless unlooked-for improvements have in quite recent times made it possible to obtain the electric light with thermo-electric piles, and we shall see that if these apparatus could be made as substantial and durable as the experiments already made seem to warrant us to expect, this system would indeed be the simplest and most economical means of solving the problem of electric illumination. In the meantime, until proof of this has been brought forward, the induction machines must still be regarded as those which best answer the various requirements of the problem, and it is these that are at the present time almost exclusively used.

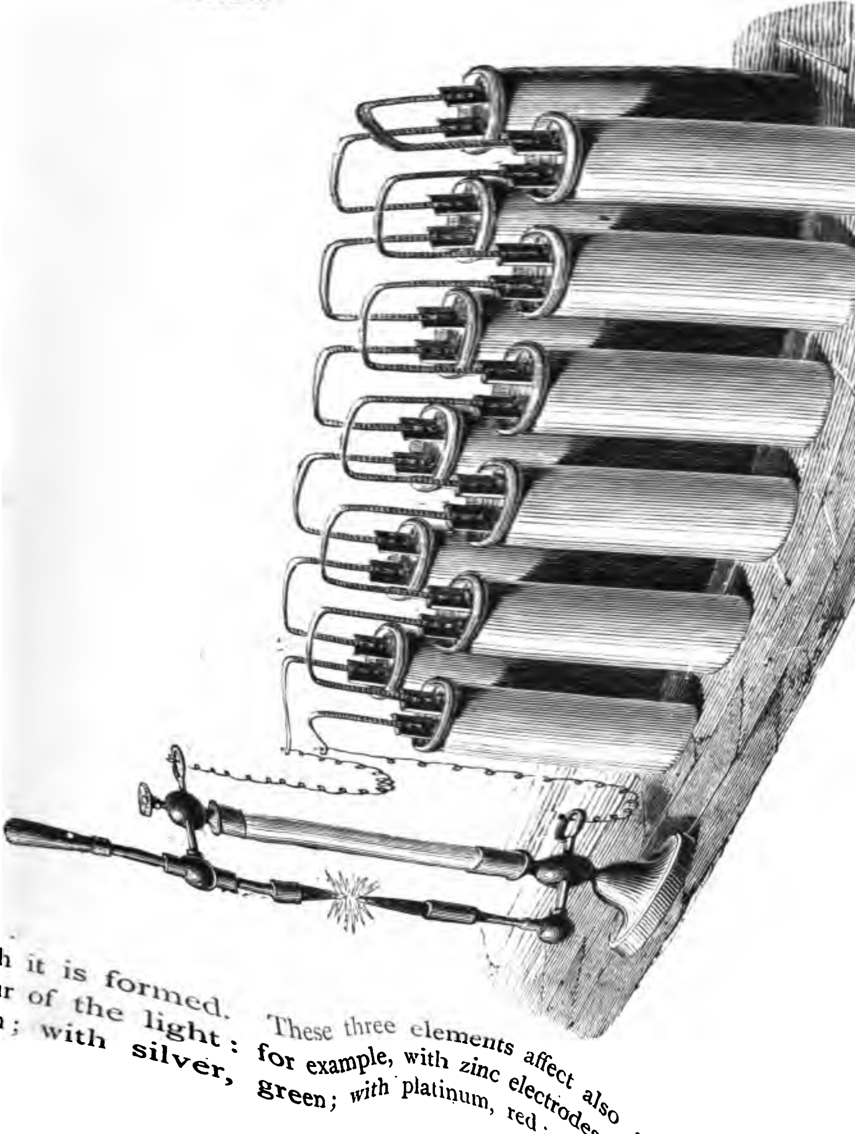
THE VOLTAIC ARC.

When the electric light is formed between two conductors separated by a stratum of gas, as shown in Fig. 1, it receives the name of *the voltaic arc*,* and under these conditions the

---

* The name of voltaic arc was given to the electric spark exchanged between two carbons, on account of the curvature of the luminous track when the stratum of air it traverses tends to rise under the influence of the high temperature to which it is subjected.

development of its brilliancy depends upon th
elements: first, the intensity of the curren
nature of the electrodes; third, the nature o



which it is formed. These three elements affect also th
colour of the light: for example, with zinc electrodes
bluish; with silver, green; with platinum, red; and

easily oxidizable metals, like potassium, sodium, magnesium, it is more intense than with the inoxidizable metals, such as gold or platinum. The shape of the luminous centre depends on the form of the electrodes and on their polarity, as I have shown in my account of Ruhmkorff's induction apparatus. Between a point and a conducting surface it assumes a conical form, and between two carbon points it has the appearance of a globe. The maximum length of the arc especially depends on the tension of the current, and with a strong current may reach to 2 or 3 centimetres when the arc has once been established. According to Despretz this length increases more rapidly than the number of battery cells employed, and the increase is more marked for small arcs than for large ones. It is, therefore, greater with batteries arranged for tension than with those arranged for quantity. Again, the voltaic arc is better developed when the positive carbon is above than when it is below; and when the carbons are horizontal the arc is shorter than when they are placed vertically, for the hot air always tends to ascend. On the other hand, the arrangement of the battery for quantity then becomes more advantageous than the arrangement for tension.

When voltaic currents are transmitted by carbon electrodes, the positive electrode has a much higher temperature than the negative, a circumstance which does not occur when induced currents of high tension are used to produce the light. With a moderate electric intensity, and with very pure carbons, the luminous effect emanates from a bluish radiant centre only; but when the intensity is greater, a real flame always surrounds that luminous centre, and the less pure are the carbons the larger is the flame.

Fig. 2 shows the appearance of the carbons producing the electric light when the voltaic arc is projected on a screen. Under these conditions the brightness of the flame, and that of the arc itself, are so far surpassed by that of the carbons that they can scarcely be distinguished. If the carbons are

conical they are unequally brilliant; the positive co
white to a considerable distance from the point, w

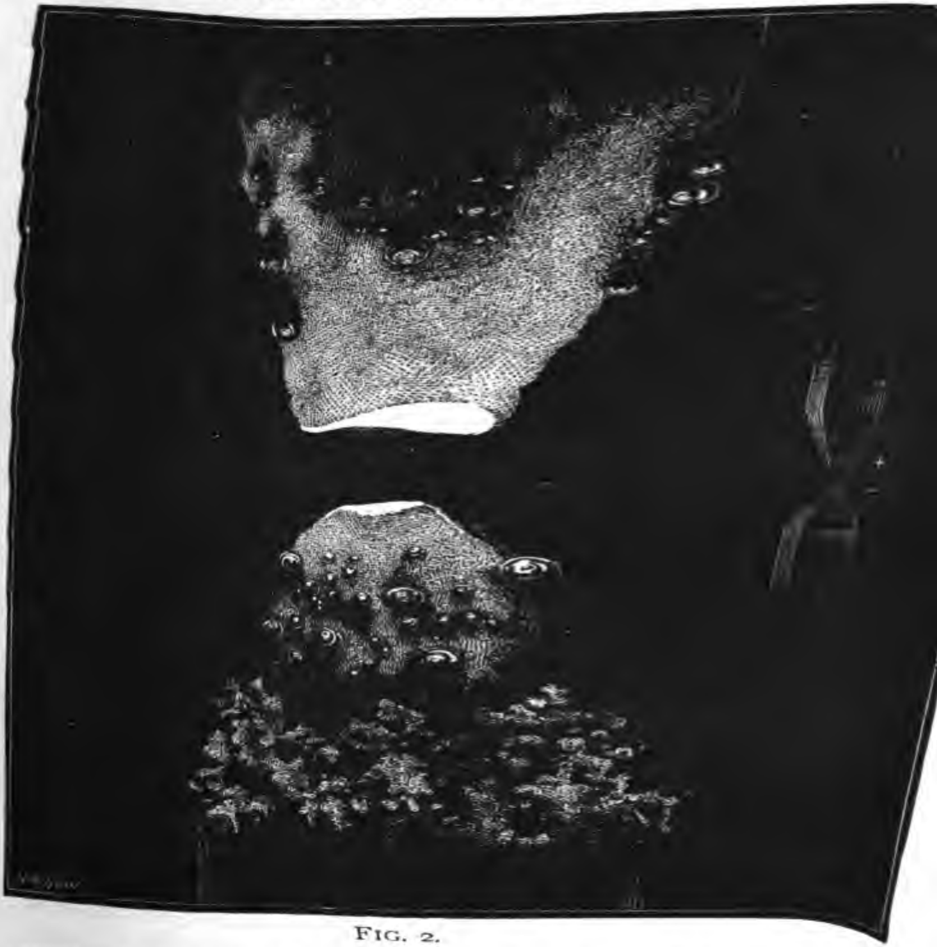


FIG. 2.

negative cone is merely reddened at its extremity; and here and there on each of the carbons are seen incandescent liquid globules, which move about and glide to the point of the carbon, whence they dart across to the opposite electrode. These globules are due to mineral substances, and, among others, to the alkaline carbonates usually contained in gas-retort carbons, which fuse under the excessively high temperature of the voltaic arc. These globules, which are not formed with very pure carbon, disturb the fixedness and constancy of the light.

When the voltaic arc is produced in the air the two carbons are soon consumed by burning, but on account of the different physical conditions of the two electrodes, and the transport of carbonized particles by the current, one of the electrodes—the positive—burns much more quickly than the other; and that in the proportion of two to one. This unequal consumption occasions several inconveniences: in the first place, a displacement of the luminous point, and, besides this, a disfigurement of the polar extremities of the two electrodes, one of which becomes more pointed, while the other is hollowed out in the form of a crater, thus surrounding the luminous point with a more or less prominent rim, which acts as a shade. The polarization effects induced on the electrodes themselves give rise to somewhat complex effects, which result in an elevation of temperature, and ought to be taken into consideration. With currents alternately reversed, like those supplied by the induction machines of the *Alliance* Company, these inconveniences do not exist; the consumption of the carbons is equal and regular, and their points, always remaining perfect in shape, give out the light in its entirety. With regard to this matter, what at first was supposed to be a defect in the magneto-electric machines, and a defect which must be corrected by means of reversing commutators, is, on the contrary, an advantage, not only by avoiding the loss of current which takes place through these commutators, but by the better conditions under which the work is produced.

These effects, however, have not been regarded in England in the same way as they have been by us, and in a report drawn

up in that country by a Commission of dist
cians, such as Tyndall, Douglass, Sabine, &c
the concavity formed in the positive ele
proper disposition of the negative carbon, be
what is termed a *condensed* light, which consi
the light emitted in a given direction. Conse
ing to these gentlemen, the light supplied
rents is much preferable to that which results from currents alternately reversed. We give farther on, however, in a table drawn up by Douglass, the difference of intensity of the two lights, with or without rectification of the currents. In order to obtain the best possible effects it is necessary, according to Douglass, *that* the lower carbon, which is the negative *one*, should be placed as shown in Fig. 3, so that *its* axis may be in the prolongation of the side
of the upper carbon, which faces the part of th
quired to be illuminated; the concavity, the bott
is the most luminous part of the arc, then ac
flector, and its brilliancy is not concealed by t
the crater round the luminous centre. “On
their loss of current and feebler action,” says Do
machines of the *Alliance* Company and those of
far from being equivalent to the new machines wi
currents, and in the application of the electric lig

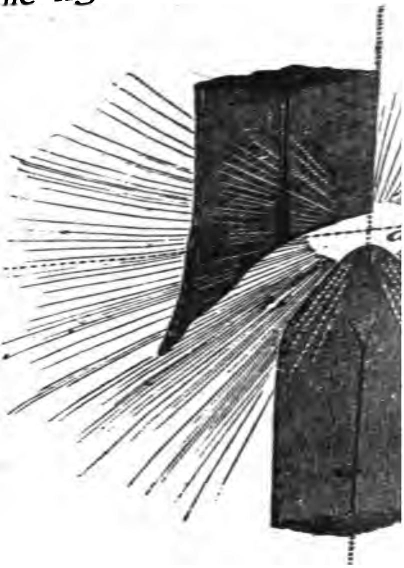


FIG. 3.

houses it is better to use these last, for the angle within which the electric light has to be projected seldom exceeds 180°, and if the carbons are placed as stated above, the light is increased in a proportion the mean of which is 1·66 to 1. It is, of course, necessary that the positive carbon should be above, and the negative carbon below."

In a report made by an American Commission on the light produced by different induction machines, the following values are given for the luminous intensities yielded in different directions by this arrangement of the carbons:—

In front	2,218 candles, or	231·0 Carcel lamps.
On one side ...	578 "	60·2 "
On the other side	578 "	60·2 "
At the back ...	111 "	11·5 "

This gives a mean of 871 candles. Now the light produced by this same machine under the same conditions, but with the carbons placed in a line with each other, yielded an intensity of only 525 candles. "This would seem to show," says the report in question, "that an increase of nearly 66 per cent. of light is due to the arrangement of the carbons; but a close examination has shown that the fact is not so, and that upon the whole there is no advantage in using this arrangement except when the light is to be transmitted in one direction only." *

The resistance of the voltaic arc is rather variable, being dependent upon the state of ignition of the carbons, and therefore upon their size and the distance between them;

---

* In Douglass's report these differences of illuminating power were represented by the following figures (the illuminating power of the light produced by the carbons placed in a line being 100):—

In front	287, or	2·87 times stronger.
On one side	116 "	1·16 "
On the other side...	116 "	1·16 "
Behind	38 "	0·38 "

The mean would therefore be in favour of the light emitted under the conditions we are speaking of, a smaller luminous power than that obtained by the American Commission.

but it may be assumed that under the conditio light, this resistance may reach two or three thous of telegraphic wire, say of 20 to 30 ohms. The fig by different physicists are, however, far from being a for while Preece, Schwendler, and others assign to resistance of 1 to 3 ohms, Ayrton and Perry fix th at from 20 to 25 ohms, at least with batteries; but it that with machines the resistance is less.

An interesting fact has been observed by Le Roux, r that if the voltaic arc is not formed in the cold wh carbons are separated by a layer of air, however sn may be spontaneously developed from one carbon to an across a space attaining nearly 3 millimetres, and afte current has been interrupted during a period which ma for about $\frac{1}{25}$ of a second. This explains why the altern reversed currents of certain magneto-electric machines are to yield a continuous light, although themselves discont ous, for the current in the *Alliance* machines is periodic interrupted every one or two ten-thousandth part of a secon

We have stated that the voltaic arc depends much up the medium in which it is formed. In a vacuum the len of the arc can be considerably increased, and although th is no combustion, there occurs a disintegration of the mate particles of the electrodes, which are carried in both directi by the current, and even spread through the surroundi space. When the arc is formed in different gases its appe ance varies but little; there are scarcely any changes colour, but secondary chemical actions may occur, and th the length and colour of the arc will be modified. Of cou in gases incapable of supporting combustion the carb electrodes, although becoming disintegrated, will not bu but the brightness of the arc is diminished.

The electric light has a great analogy with that of sun, but the former contains more of the chemical ray circumstance which renders it rather hurtful to the si Means of avoiding this inconvenience have indeed at vari times been proposed, and among others the use of fluorescent globes, capable of absorbing these chemical rays; but this improvement was obtained at the expense of the illuminating power, thus making the advantages of the electric light less marked.

In comparing different luminous sources with each other, Foucault and Fizeau have found that the light of the ordinary voltaic arc is one-half less than that of the sun, whilst the Drummond light (oxy-hydrogen) is only the one hundred and fiftieth part. Now the sun throws upon a given surface as much light as 5,774 candles placed at 0·33 metre from that surface.

out of one of those residues which are taken from the retorts of gasworks after the distillation. This form of carbon is very hard, very compact, and relatively a good conductor. The communicating wires are joined to these electrodes by two brass clamps, the one of large size covering the upper part of the carbon and pressed against its surfaces, the other provided with a binding screw aperture for holding the negative wire is applied to a slip of copper riveted to the zinc cylinder. The arrangement of a cell of this battery is shown in Fig. 4.

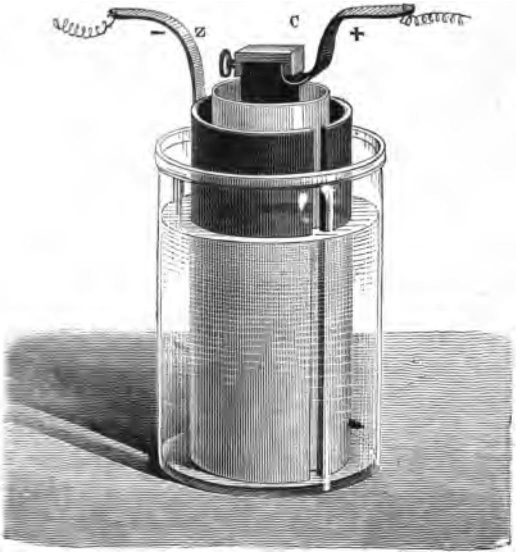


FIG. 4.

This arrangement may be reversed, and as regards the constancy of the battery there would be a gain in doing so, for, as I have shown, the effects of polarization are less in proportion as the negative electrode is larger; but as the electric light requires a great consumption of zinc, this substance must be placed in the cell in sufficiently large quantity, and the former arrangement is the mos this respect.

In Bunsen's cell nitric acid acts as a dep that is to say, as a means of preventing a carbon of the hydrogen resulting from the dec the water by the zinc. When this deposit is fo carbon, there is, in fact, an electro-motive force in consequence of the reaction of the hydrogen on which force, acting in the contrary direction to th battery, weakens the latter the more the longer th is in action, and the less resistant is the circuit. N acid, being very rich in oxygen, and readily givin permits the hydrogen disengaged in the cell to combi that oxygen, and, so to speak, intercepts it on its before it is able to produce its bad effect. On th hand, this acid, by itself acting chemically upon the acid water, develops an electro-motive force which acts same direction as that produced by the oxidation of the and this still more increases the energy of the battery.

The inconveniences of this battery are its expense an suffocating and unhealthy emanations from it. The acid, on being deoxidized, passes into the state of ni acid, which is liberated in the form of reddish-brown va that are difficult to prevent.

In order to avoid too great a consumption of zinc, to render the action of the battery more constant, the is amalgamated, the special purpose of this operation to annul the local couples which are due to the impuri the zinc, and consume it without any useful result. simplest means of obtaining this amalgamation is to plu the zinc into a liquid composed in this way:—

Two hundred grammes of mercury are dissolved by hea 1,000 grammes of *aqua regia* (nitric acid 1, and hydrochl acid 3). When the solution of the mercury is compl 1,000 grammes of hydrochloric acid are added.

The zinc is allowed to remain for a few seconds in liquid, and is then withdrawn completely amalgamated, and with 1 litre of the liquid 150 zincs may be amalgamated.

The zincs are also amalgamated by plunging them into a vessel filled with water acidulated with hydrochloric acid into which some mercury has been poured, and by rubbing them with a metallic brush dipped into mercury. But it is best to use zincs amalgamated throughout their whole mass. Dronier has succeeded in forming zincs of this kind by uniting mercury to the zinc during its fusion in a closed vessel.

Tommasi has recently arranged Bunsen's cell in such a manner as to produce the electric light under relatively good conditions. According to an article published by Moigno in *Les Mondes* of the 24 *Juillet*, 1879, Tommasi has even succeeded in making this battery inodorous by hermetically closing the porous vessels containing the nitric acid. The upper part of these vessels is enamelled, and serves as a reservoir for a certain quantity of the liquid that is periodically renewed by means of an opening which is again closed up, and a combination of syphons to maintain the contents of the outer vessels at the same level. An upper vessel containing a part of the acidulated water permits it constantly to flow in small quantity into the first of the outer vessels, distributes it by the syphons to all the cells of the battery up to the last, and this discharges its overflow into a vessel which leads it into a waste-pipe. The zincs stand in a small circular trough placed in the acidulated water, and containing mercury to keep up the amalgamation.

"After three months of constant experiments and observations," says Moigno, "we have been able to ascertain that the expenditure of the battery for a lamp by incandescence is about 1 litre of nitric acid and 2 litres of acidulated water a day, and the expenditure of the lamps is from 15 to 20 centimetres of carbon per hour."

We must add that this arrangement of the battery is nothing very novel, and we have described several systems of this

kind in our *Exposé des applications de l*
207, *et tome V.*, p. 392.

There are two important elements tc
battery—its *electro-motive force* and its r
at the beginning of this work defined w
stood by these two expressions. The laws
have been based on the constancy of tl
and hence the name of *voltaic constants* wl
to them; but as a matter of fact, on accou
reactions which show themselves, and of
effects are the principal, this is far fron
Nevertheless, as the values of these consta
approximately for all the other electric a
been necessary to calculate them, and I h
tome I. of my *Exposé des applications de l'*
et 456, those which have been obtained by
As in the present work we have hardly mor
of battery to consider, we shall merely state
motive force of the Bunsen cell represents in
motive force or in *volts* from $1^{v}\cdot888$ to $1^{v}\cdot96$
to the electro-motive force of the Daniell ce
to 1·820. The resistance of the same cell (
which is composed of that of the liquid inter
the polar electrodes, and that of the porous ve
gaseous deposits produced by electrolytic actio
tion, varies from 50 to 150 metres of telegraph
ing to the resistance of the external circuit.
because figures which are deduced from experi
to prove that this variation exists; but as this
the effects of the polarization of the electrodes
affects the resistance of the cell only because the
circuit is discharged from it, it may quite as well
to the whole circuit as to one of its parts. How
resistance other than that which it really possess
be given to the metallic circuit, it is convenient to
to that of the Bunsen cell the value of 50 metres

circuit has little resistance, and that of 100 to 150 metres when the resistance is large. The values which we have just given relate only to a cell with fresh liquids; but these are rapidly changed as the nitric acid becomes deoxidized and the acidulated water becomes charged with sulphate of zinc from the corrosion of the metal. To restore the condition of the cell it often suffices to pour a little water into the outer liquid, and to add to the nitric acid some concentrated sulphuric acid, which, having great attraction for water, dehydrates the spent nitric acid.

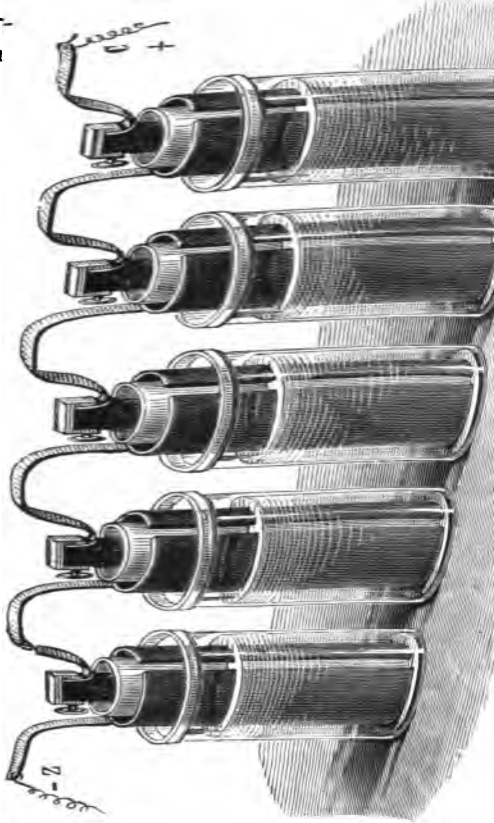
I enter into many details on this battery, and on all others, in the first volume of my *Exposé des applications de l'électricité*, and this renders it unnecessary to speak more about them here. Their profound study would be altogether beyond the purpose of this work; it is sufficient for us to describe the mode of arranging the foregoing battery, in order that in the application which may be made of it to electric lighting it may be known upon what we have to rely.

In order to obtain the electric light with a Bunsen's battery, it is necessary to group together a certain number of cells, and the mode of grouping these cells depends upon the kind of light which it is desired to obtain. If the light is to be supplied by a voltaic arc, that is to say, with a gaseous interval between carbon electrodes, it is necessary to group the cells *for tension*, that is to say, by their opposite poles, a positive pole with a negative pole, as shown in Fig. 5, and at least 30 cells are necessary; generally 60 are used for most of the experiments that are made at theatres, or for the lighting of works by night, and even then only one lamp can be lighted. When it is desired to light several, a much more powerful battery must be used with certain lamps. We shall speak of this farther on.

If the light is to be the result of an incandescent effect, the battery gains by being arranged for quantity; that is to say, arranged in such a manner that all the cells are joined by their like poles. The calorific effects are then increased

at the expense of the tension effects, and for inc
calorific effects are especially necessary.

Finally, if by reason of the resistance of the exte
or the condition of the experiment, the electric current must have both tension and quantity, the cells are arranged *in series*, that is to say, in groups composed of a greater or less number of elements joined for quantity, and these groups are themselves joined for tension.



By means, therefore, of a battery of several cells or elements, we may obtain those various effects that are peculiar to batteries of a greater or less electromotive force; but we must remember that when several cells are joined for quantity, that is to say, by their like poles, *we do not thereby increase the electro-motive force of the generator;* this electromotive force always remains the same as that of a single cell, but *the resistance is diminished in proportion to the number of cells joined together*, or, which comes to the same thing, a cell of larger surface is formed. It must also be borne in mind that the electro-motive force of a battery *does not depend on the size of its elements, but on the nature of the physical and chemical actions that arise within it*, and on *the number of elements that are joined by their dissimilar poles.* But as this isolation of the action of each element increases the resistance of the battery as a whole, it may happen under certain conditions of the external circuit that more force may be lost by the increase of the total resistance of the battery than is gained by the increase in the number of its elements; and this is why it is necessary when determining the arrangement of a battery to know exactly the conditions of the external circuit on which the battery is to act, and more particularly the resistance of that circuit.

The great principle which must guide us is that the battery should be so arranged that *its own resistance shall be equal to that of the external circuit.* If the 50 metres of telegraph wire we have given be accepted as the resistance of a Bunsen's cell, and if the resistance of a voltaic arc in the ordinary electric lamps be estimated at 3,000 or 4,000 metres of such wire, it will be seen at once that there is an advantage in arranging for tension the elements of a battery used for electric illumination by the voltaic arc, and that at the same time it is an advantage to have cells of large size, not in order to give a greater electro-motive force, but to enable its action to last longer and to increase its calorific power. If the electric light is to be produced by incandescence, the resistance of the circuit becomes very much less (about 33 metres for the incandescent part); and there is a gain, on the other hand, in arranging the battery for quantity or in series, according to the number of lamps it has to supply and the arrangement of the circuits. It is certain that if in the same circuit a certain number of lamps be included, the battery must have more tension than when the lamps are arranged in distinct or *derived* circuits, and the mode of arrangement to be given to the battery will still be determined by the total resistance of the external circuit; which, in that case, will equal the resistance of one of the lamps divided by the number of lamps to be lighted. It will be understood that in this case the electricity supplied by the battery is simultaneously distributed among all the circuits, as the water of a reservoir would be among several discharge-pipes, and that the resistance then opposed to the propagation of the electricity is equivalent to that of a single conductor of a section as many times greater as there are *derived circuits.* Now as the electric resistance of a conductor is in inverse proportion to its section, it will be at once seen why in this case the battery must be arranged in such a manner as to have its resistance greatly lessened.

It is not necessary that the several elements of a battery should be directly connected together; they may be joined by conductors of greater or less length. For instance, one part of the battery may be at one end of the circuit, the other part at the opposite end; and according to the manner in which these two parts are connected by the two conductors of the circuit, we shall have a battery arranged for tension, or with a double surface (quantity). Only in this last case will it happen that all the connecting wires between the two conductors will transmit the current with exactly the same intensity, at whatever point of the circuit the junction may be made. This will be easily understood, if we reflect that the connecting wires of the two parts of the battery then form electrodes charged to the same potential throughout their whole extent, and that the poles of the battery will then be placed at the two points where the wires are attached that are to supply the work.

If the resistance of the external circuit and that of an element of the battery are known, the most suitable arrangement for the elements of the given battery can be immediately determined without trial by means of the two following laws, which I have discussed at length in my *Exposé des applications de l'électricité, tome I.*, p. 145.

1°. The number of elements in each group to be arranged for quantity is given by the whole number nearest to the square root of the product of the total number of elements in the battery into the resistance of a single element, divided by the resistance of the external circuit.

2°. The number of groups which must be connected for tension is given by the whole number nearest to the square root of the product of the total number of elements in the battery into the resistance of the external circuit, divided by the resistance of a single element.

One of these determinations will, however, suffice, for if it be known how many elements are to be connected for quantity in each group, the total number of elements divided by that of each group will give the number of groups that must be connected for tension.

The amount of the resistance of the external circuit is ascertained by employing an apparatus known as the *Rheostat*, and a kind of electrical balance which may be a *differential galvanometer* or a *Wheatstone's bridge*. These pieces of apparatus, and the mode of using them, being described in all treatises on physics, and particularly in our *Exposé des applications de l'électricité*, we shall not further occupy ourselves with them : we shall state only that the total resistance of the derivations of a circuit may be obtained by the following equation :—

$$\frac{1}{T} = \frac{1}{d} + \frac{1}{d'} + \frac{1}{d''} + \frac{1}{d'''}\ \&c.$$

in which T represents the total resistance, d, d', d'', d''', &c., the resistances of the several derivations. From *this the* value of T can be calculated when we know the values of d, d', d'', &c., or the value of any one of the derivations can be found when we know that of the rest and of T.

I should have wished, in such a work as I am now writing, to avoid mentioning these different calculations, but as they are indispensable if we wish to understand the question, and besides are very simple, I have considered it my duty at least to indicate them. Further, there is a general principle which is found in nearly all electrical effects capable of a maximum, and which ought always to be present to our minds. It is this: in order to be under the best conditions, the electrical generators must be arranged in such a manner that *their internal resistance shall be equal to that of ternal circuit;* and if the circuit is composed of two one serving simply for electric transmission, the other f production of a calorific or electro-magnetic work, it is n sary that *the resistance of the inactive circuit, including t the battery,* shall be equal to the resistance of the electro-mag *organ,* or to that of the conductor developing the calorific e

Mode of Propagation of Electricity.—Before st ing the magneto-electric generators, which have solved problem of electric lighting, it seems to us important to g some details as to the conditions of charge and discharg a circuit, and as to the mode of propagation of a curren

It is often asked in what conditions are the insulated w of a circuit in connection with the battery when that cir is not *closed,* and one would be apt to suppose that in or to produce a movement of the charge it would only be ne sary to put a conductor in communication with one or ot of the electric poles. But matters do not happen quite this way.

To charge conductors it is necessary that the positive a negative charges shall be able to flow in the same prop tion. Thus, a very long conductor applied to the positi pole of a battery can be charged only when the negati charge can be transmitted to a conductor of the same leng attached to the negative pole, or when that charge is able flow away into the earth. Then the charge is successive transmitted to the end of the positive wire, and when it h there reached the same tension as near to the battery, th current which resulted from that transmission ceases, and th whole of the conductor is charged to the potential of th battery. When this positive wire is placed in communicati with the ground a new electric movement is produced, b ginning at the end of the wire, and a discharge current obtained which now is continuous and constitutes the cu rent properly so called.

It follows from this mode of action that when a complete circuit is closed near the battery, the current at first sets out from the two poles of the battery, and produces its effect in the centre of the circuit last; so that at the first instant one-half of this circuit is traversed by a positive charge, and the other half by a negative charge. But this takes place only when the circuit is wholly metallic. If the earth is interposed the positive charge traverses the whole length of the wire, for the negative charge is then completely absorbed by the earth.

For a long time it was supposed that the charge of a circuit was in a manner instantaneous, and that it had its limit of velocity only in that of electricity itself, a velocity which was believed to approximate to that of light; but a deeper study of the mode of propagation of electricity showed that this was far from being the case, and that, in fact, properly speaking, there was no such thing as a velocity of electricity, but rather a period of electric fluctuations during which each point of the circuit incessantly changes its electric tension. Hence we were led to assimilate the propagation of electricity to that of heat, and for the first time were able to form a clear conception of the effects of electric transmission on our long telegraphic lines.

It was in 1825 that the illustrious Ohm made the discovery upon which he founded the theory which bears his name, and which modern discoveries have only served more fully to justify. Nevertheless, this theory was not at first received by the scientific world with that favour which its author had a right to expect; he was on account of it even subjected to a persecution that compromised his position as professor; and it was only ten years later, when Pouillet had arrived at the same laws by experiment, that people began to revise the sentence they had pronounced against Ohm and to appreciate the merit of his discovery. Yet while adopting the formulas of the illustrious mathematician, physicists were, until the year 1860, unwilling to accept the

assimilation of the mode of prop
of heat as propounded by Ohm,
tion they thus assumed they a
results regarding the velocity of
they were obliged to admit that ei
for the measurement of that vel
ducted, or that the commonly acc
gation of electricity were false.

About the year 1859, Gaugain, a
for some time been engaged in
regards the transmission through b
investigated the causes of this disc
the solution of the enigma. He asc
so far from being propagated like lig
intensity in every part of its course
as Ohm had found, be transmitted
heat is propagated in a bar of metal
maintained at a lower constant temp
In this case the heat is communicated
beginning at the heated end of the b
the calorific movement is propagated
the parts first heated acquire a greate
heat, until when the calorific moveme
end, the different points of the bar lo
one side as they gain on the other.
equilibrium established, and the dis
parts of the bar remains constantly
condition called by physicists *the*
But before a metallic bar arrives at th
elapse an interval of time, longer or
calorific conductivity of the bar, duri
of the heated body is continuously c
If the assimilation of the propagatio
tion of electricity be correct, a like
during the first moments of the p
According to this hypothesis an el

nothing but the result of the tendency to equilibrium, from one end of the circuit to the other, of two different electrical states, determined by the action of the battery, and representing, therefore, the two different temperatures of the heated bar. This variable period must no doubt be excessively short on account of the subtilty of the electric fluid, but with circuits of great length and with those formed of bad conductors it may be measured, and this, in fact, Gaugain found by experiment. He thereupon investigated the laws of the transmission of the current during this variable period, and, among other laws, he found that the time required for a current to attain its permanent condition in a circuit, that is, to acquire all the intensity of which it is capable, is *proportional to the square of the length of the circuit.* This had not only been foreseen by Ohm, but had even been mathematically formulated by him in the equation representing the tensions of the different points of a circuit during the variable period of the current's intensity.

THERMO-ELECTRIC GENERATORS.

The thermo-electric piles invented by Seebeck in 1821 had for a long time been regarded merely as generators of great constancy, capable of being very advantageously used in scientific experiments, but incapable, on account of the weakness of their currents, of being applied in practice. But the application which, some years ago, Marcus made of the considerable thermo-electric power of metallic alloys, [*]

---

[*] The discovery of the great thermo-electric power of metallic alloys was made in the first instance by Seebeck, who even mentions the alloy of antimony and zinc as one of those which might be most advantageously used; but these thermo-electric systems were not applied until ten years afterwards,

and the possibility of heating t without damaging the pile, mad electric batteries enter upon a new with success by several physicists, Bunsen, Ed. Becquerel, Clamond, be obtained having an electrical that of the battery cell with acids, with much advantage, even in el apparatus of this kind, those which were beyond dispute Clamond's pil

From the first, that is to say, in that he might one day be able to with this kind of battery; and here in my *Exposé des applications de l'él* published in 1871:—

"Mure and Clamond are now constr kind having 1,500 large elements, whicl power equal to 50 Bunsen cells. If, as expect, the expense occurs under the sam case considered (heating by coke), it will per hour, and the thermo-electric pile r economic source of electric light."

This result, however, could not be at of the unfavourable conditions under w placed, and because the galena which Cl was damaged by the heat. Nevertheless,

and the combination which develops the highest electr pointed out by Ed. Becquerel, in which one of the bars mony and cadmium in equal equivalents, and the other antimony, the last forming only a tenth part of the alloy searches this combination gives the best results, but for ind it cannot easily be used. In the first place, the cost of th be extremely great, and secondly, the system could not high a temperature as one formed of other alloys. There tion of antimony and zinc with sheet-iron, adopted by Clan of itself giving so great an electro-motive force, is capable c results by reason of the greater difference of the temperatu imparted to it.

sufficed to convince him that the problem might one day be solved, and this, in fact, is what we now see. In order, however, to arrive at a result so important as that which we have stated, Clamond had to devote himself to a great number of experiments and numerous investigations, and it was only after nine years had passed that he was able to solve the problem completely. One of Clamond's piles, arranged nearly like a heating apparatus, and having its dimensions not greater than 1·50 metres in height and 80 centimetres wide, is now able to supply three electric lamps, each equal to from 15 to 20 gas-burners, and requiring for the whole expense of the supply of electricity, the burning of only 9·5 kilogrammes of coke per hour. It will be seen that this is a considerable result, and the more important since an apparatus of this kind does not require the attention of a mechanic or skilled workman. The apparatus may be placed in a cellar and so arranged that it may be used as a heating apparatus, and any person is able to work it, since it needs only to be heated like an ordinary stove.

But let us state on what principle this ingenious apparatus is founded.

If pieces of two different metals are soldered together by one end of each, and the soldered portion be heated, the movement of the heat takes place differently in the two metals, and gives rise to an electro-motive force which supplies an electric current that may be collected from the free extremities of the metals. The simple metals, the junction of which affords the most marked thermo-electric effects, are bismuth and antimony; but, as we have already said, alloys and certain metallic minerals give effects much more powerful. At first Clamond's pile was made of bars of galena soldered to plates of sheet-iron; but he soon had to abandon the use of galena, and he resorted to an alloy composed of antimony and zinc, while still retaining sheet-iron as the electro-positive plate. By arranging these elements in a ring, placing several of these rings one above the other,

and throwing the flame of a central
junctions of the elements within the ri
obtain with a battery of somewhat small d
tric current equally powerful with that fro
cells. But in this arrangement the electro-
the couple was in proportion to the differenc
temperatures at the ends of each bar, and there
to obtain a powerful effect, it was necessary t
should be rather long, and this led to a great
the resistance, for these heated alloys have muc
sistance than would at first be supposed. The
also required a useless consumption of the heat,
radiation and by contact with the air, escaped from t
surfaces of the prism without having traversed th
length of the bar, and therefore did not yield the m
of the useful effect of which it is capable as regards it
mutation into electricity. Again, it often happened th
apparatus received an excess of heat, and the metal
round the parts of the iron plates to which it was solde
For these reasons Clamond was unable to use this ki
pile for the great effects he was seeking to realize. He
therefore, to completely alter the original arrangement o
pile, and after numerous attempts he arrived at the ver
markable arrangement we are going to describe.
original Clamond piles are, nevertheless, still used at
present day in the workshops of Goupil and others, wh
they continue to work with regularity.

“In my new arrangement,” says Clamond, “I have striven
avoid all the defects previously enumerated, and for this object
have formed the apparatus of three entirely distinct parts.

---

* “The use of flames or of radiating surfaces,” says Clamond, “rend
the heating of the couples very difficult to regulate, and it is seldom adop
except for apparatus of small dimensions, and when gas is the combustib
Besides, the surfaces to be heated (which are represented by the sections
the couples or of the polar projections with which they are sometimes pr
vided) being very small, but little of the heat produced by the flame is tak
up, and the products of combustion pass off at a very high temperature.

"1°. Of a *collector*, which is a series of light pieces of cast iron of such shapes that they present a succession of canals in which circulates the heated air supplied by any source of heat. These pieces present a very large surface to the motion of the hot gases, which leave them at a temperature but little removed from their own; they store up the heat which they afterwards communicate to the couples.

"2°. Of a *diffuser* of the caloric forming the outside of the apparatus, and made of metallic plates, presenting a considerable surface for the circulation of the surrounding air.

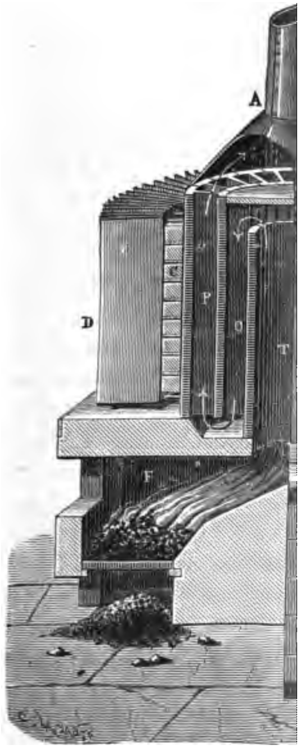
"3°. Of the *thermo-electric arrangement* properly so called, which is placed between the collector and the diffuser, so that the opposite series of junctions participate in the different temperatures of these two organs. The flow of heat takes place from the collector to the diffuser through the couples, parallel to their length, and without appreciable loss of heat by the lateral surfaces, thus realizing the maximum amount of transformation of which the substances used are capable."

These several plans have been realized in the apparatus represented in Fig. 6, the arrangement of which also admits of being varied.

In this apparatus the collector is formed by a cast-iron cage T O P, arranged nearly like a stove for smoothing irons, underneath which is the fireplace F, wherein coke is burnt. This cage is so formed that the current of hot air which is to supply the heating effect, after having thrice circulated about the apparatus by means of the chambers T O P, escapes by the draught chimney A, and may, by means of stove-pipes properly arranged, be used to warm a room. Externally this cage forms a polyhedric surface of many faces, on which the thermo-electric piles C are arranged in rows as shown; and upon these rows the diffusers D are applied.

The diffusers are made of plates of copper arranged like the leaves of a book, and are soldered on flat bands of the same metal, which by means of screws are pressed firmly against the rows of the thermo-electric couples. These plates, by the large surface of contact they present to the air,

readily part with much of tl
and thus occasion a great
opposite junctions of the tl
diffusers enable the length o



Fi

be reduced without inconven
understood that the diffusers,
ating surface, will emit much l
ratus capable of being used a
for warming an apartment.

The thermo-electric elements are here differently arranged in [illegible] rows, [illegible] one of which is shown in Fig. 7. The negative elements, instead of being made of small elongated prisms of an alloy of antimony and zinc, are replaced by little cubes [illegible] centimetres square [illegible]. These little cubes are connected by plates of tinned iron bent like the letter L, as in Fig. 8, and having their ends soldered to the opposite faces of two adjoining elements. The plates are locked with the little cubes by the juxtaposition of the sheets, and in order to avoid metallic communication they are covered with asbestos paper. The parts of these plates which are soldered with the cubes are, moreover, cut so as to form a kind of teeth twisted helically, thus insuring good contact with the alloys to which they are soldered. The construction of the rows is, however, very easy, for they can be cast at a single operation of any desired length. In order to do this it is necessary merely to place between two cast-iron rules the series of sheets of tinned iron bent into the L form, and to cast the alloy over the whole; the parts of the plates covered with asbestos paper separate the elements without further trouble. These rows, pressed between the collector and the diffuser, from which they are suitably insulated by a covering of asbestos paper, as shown in Fig. 8, can be connected together by their free extremities, so that any desired connections and combinations may be effected.

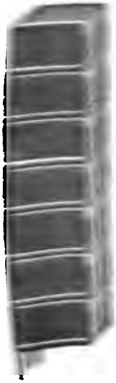


FIG. 7.

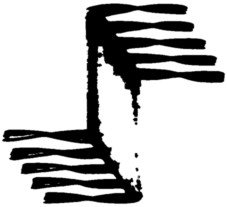
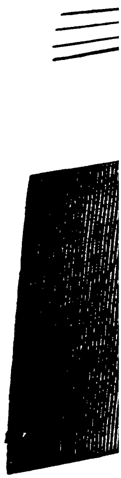


FIG. 8.

Clamond has constructed two patterns of this kind of pile; one, which has for some time been at work at No. 25 in the *Rue Saint Ambroise*, lighting a workshop; the other, which was put together in such a manner was intended for the electric light Hall, London. The first form is metre in diameter, the second 1·5 metres wide. This last form, instead square, but it has the same electrical compact.

The first form, represented in Fig. tinct superposed piles, and the furnace is below exactly as shown in the figure.



In each half of the apparatus there are thirty rows of 100 elements, or 3,000 elements, making in all for the two superposed apparatus 6,000 elements. It is in the outer faces of these rows that the plates of copper which form the diffusers are fixed.

Each part of this pile can supply an electric light equal to 40 Carcel lamps. The total electro-motive force is 218 *volts*, or about 120 Bunsen cells; and the total resistance is 31 *ohms*, or 3,100 metres of telegraphic wire.* This large pile requires, as we already said, only 10 kilogrammes

In the apparatus intended for the Engl space is considerably reduced, and the row so arranged as to form four different current capable of producing a light equal gas-jets. In this way four luminous instead of two.

---

* These determinations were made by Cabanellas, Electric Light agency.

The thermo-electric elements are, as we have seen, arranged so as to form rows, and they appear as shown in Fig. 7. The negative elements, instead of being made of small elongated prisms of alloy (antimony and zinc), are reduced to little almost cubical blocks, 3 centimetres square by 2 deep. These little cubes are connected by plates of tinned iron bent like the letter Z, as in Fig. 8, and having their ends soldered on the opposite faces of two adjoining elements. The plates are locked into the joints formed by the juxtaposition of the cubes, and in order to avoid metallic communication they are covered with asbestos paper. The parts of these plates which are soldered into the cubes are, moreover, cut so as to form a kind of teeth twisted helically, thus insuring good contact with the alloys to which they are soldered. The construction of the rows is, however, very easy, for they can be cast at a single operation of any desired length. In order to do this it is necessary merely to place between two cast-iron rules the series of sheets of tinned irons bent into the Z form, and to cast the alloy over the whole; the parts of the plates covered with asbestos paper separate the elements without further trouble. These rows, pressed between the collector and the diffuser, from which they are suitably insulated by a covering of asbestos paper, as shown in Fig. 9, can be connected together by their free extremities, so that any desired connections and combinations may be effected.

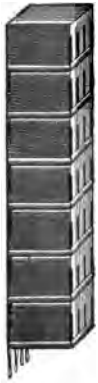


FIG. 7.

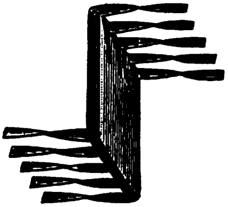
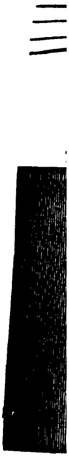


FIG. 8.

Clamond has constructed two patterns of this kind of pile; one, which has for some time been at work at No. 25 in the *Rue Saint Ambroise*, lighting a workshop; the other, which was put together in such a manner was intended for the electric light Hall, London. The first form is metre in diameter, the second 1·5 n metres wide. This last form, instead square, but it has the same electric compact.

The first form, represented in Fig. tinct superposed piles, and the furnace is below exactly as shown in the figure.



In each half of the apparatus there are thirty rows of 100 elements, or 3,000 elements, making in all for the two superposed apparatus 6,000 elements. It is in the outer faces of these rows that the plates of copper which form the diffusers are fixed.

Each part of this pile can supply an electric light equal to 40 Carcel lamps. The total electro-motive force is 218 *volts*, or about 120 Bunsen cells; and the total resistance is 31 *ohms*, or 3,100 metres of telegraphic wire.* This large pile requires, as we already said, only 10 kilogrammes c

In the apparatus intended for the Engl space is considerably reduced, and the rov so arranged as to form four different pi current capable of producing a light equa gas-jets. In this way four luminous cen instead of two.

---

* These determinations were made by Cabanell Electric Light agency.

MAGNETO-ELECTRIC GENERATORS.

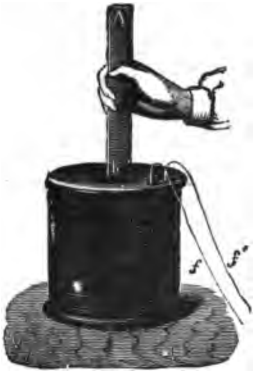


FIG. 10.

The method of generating electricity by chemical action, and especially by the oxidation of zinc, is, as will presently be seen, extremely costly, and if this were the only way of producing the electric light, that method of illumination could not be entertained; but it is not the only way, for, thanks to the powers of induction, generators of the light have been formed which require nothing more than motive power, and this brings the production of electricity to the matter of a greater or less consumption of coal, which is of all chemical reactions the simplest and cheapest. In this respect the results obtained have exceeded all expectations, and it may be said that if the solution of the problem depended only on the production of electric action, it has now been almost realized; for, light for light, the cost of illuminating in this way would be ever so much less. But the question is, as will be seen, much more complex, and until we have treated it from the various points of view that require to be taken into consideration, the generators founded on the effect of induction will engage our attention.

History of the Question.—When a voltaic current circulates spirally round a core of iron, steel, or any magnetic substance, the latter is magnetized, and, with certain magnetic substances possessing, like iron, a non-persistent coercive force, this magnetism disappears as soon as the current

ceases to circulate in the metallic s
ductor. This phenomenon, first obs
Arago a short time after the disco
effects of currents on the magnetic n
point of electro-magnetism and of th
chanical applications of electricity.

By reasoning according to the pr
actions, it might have been deduced a
nomenon that a permanent magnet by r
circuit would cause an electric current in

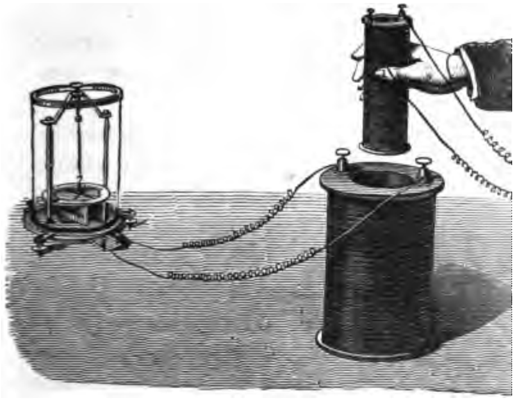


FIG. 11.

was ten years afterwards, that is to say, abou
illustrious English physicist, Faraday, first pro
of this phenomenon and determined its va
istics. Numerous experiments instituted by
subject showed that if a magnetic bar be
coil covered with insulated wire, or if a seco
by a current be so thrust, as shown in Figs
energetic current capable of affecting a gal
fact, induced in the first coil. But there
peculiar circumstance which theory could n

one to foresee *a priori*, and that was that the current is merely temporary, for it ceases immediately, giving place to another current equally transient which shows itself at the instant the magnet is withdrawn from the coil. This latter current has its direction opposite to that of the former, and if the direction of these currents be compared with that of the magnetic or voltaic current which gives rise to them, it will be observed the directions are the same for the latter current and opposite for the former. Hence the name of *direct current* given to the current which shows itself in the second case, and the name of *inverse current* given to that which is produced in the first case. Thus the mere approach of a permanent magnet to, and its recession from, a spirally arranged circuit give rise to two opposite instantaneous currents which are distinctly separate.

These instantaneous currents may, however, successively appear one after the other, from one and the same movement of the inducer or of the induced circuit, if this movement is successive; for at each stage of this movement there is produced a differential induced current which continues the action of the former, and all these currents joining one to another may give rise to a current of appreciable duration, which may be in one direction or the other, according as the movements succeed each other in the direction of approach or in that of recession. This current, however, is feebler at any given instant than that which would result from the same total movement suddenly effected through the same space. We shall see farther on what is the effect of quicker or slower movements with respect to the nature of the induced currents developed by them; but here it may be stated that quicker or slower movements through the same space affect only the *tension* of the induced current.

When these principles were once recognized, it only remained to mechanically combine the different elements producing these temporary currents, so as to rectify them and cause them to succeed each other without interruption.

Several mechanician
Pixii, Clarke, Page, N
only to cause to re
magnet an electro-ma
with a quantity of wir

FIG.

action to be developed in all it
ment the electro-magnet is, in fa
ing the poles of the permanent
a magnet it produces in the wir
current, which gives place to a di
electro-magnet begins to lose its n

the ends of the induced wire, that is to say, of the wire of the electro-magnet, are connected with a commutator for reversing the poles placed on the axis of rotation of the system, the two currents traverse the circuit always in the same direction. Such are the magneto-electric machines, the original type of which is represented in Fig. 12, but their arrangement has, however, been varied in many ways. It is these that have given birth to the powerful machines which in recent times have astonished physicists themselves.

While some were making the magneto-electric machines of which we have just spoken, other physicists and mechanicians were setting up new forms of them, by availing themselves of the inductive effects of voltaic coils which allowed induced currents to be obtained without the necessity of turning any machinery. Such coils being placed within the coil intended to supply the induced currents, could play the part of magnetized bars, since, as Ampère showed, they constituted *dynamical magnets;* and in order to obtain the effects produced by the approach or recession of the inducing coil (that playing the part of a magnet), it sufficed to place in the circuit an automatic interrupter of the current. By the year 1836 Page in America, Masson in France, and Callan in England had in fact constructed machines of this kind, in which the induced currents could be thoroughly studied and their character determined; so that it was established with certainty not only that induced currents possessed high tension, but that under certain conditions they were able to produce some effects resembling those of static electricity. These pieces of apparatus, improved by Page, Callan, Sturgeon, Gauley, Masson and Bréguet, Bachhoffner, Clarke, Golding Bird, Nesbitt, Breton, Fizeau, Ruhmkorff, Cecchi, Hearder, Bright, Poggendorff, Foucault, Bently, Ladd, Jean, Ritchie, Gaiffe, and Apps, were not long in becoming powerful generators of high tension electricity, able advantageously to supersede electric machines, and they constitute at the present day the most

important and most interes
power and variety of their ef

From this rapid review it
duction machines may be di
1°, those which have for ind
voltaic current, and in which th
current itself; 2°, those which
ent magnet and require a mecha
their effect. But besides these tw
is a third, the powers of which
gated, and which, while belongin
have just spoken of, present this
apparatus do not require permane
and that the inducer, made of s
magnet, and a most powerful ma
of the induced current it produc
stance in these apparatus is that
speak, inappreciable; it is a slight
cated to the iron, either by the m
by a residual magnetism: in proport
apparatus the initial cause and the
developed until the limit of maximu
is reached. These interesting machin
taneously by Wheatstone and by S
proved by Wilde and by Ladd, and
ment many other machines contrived
by this addition have acquired a ve
Finally, to bring this historical sket
shall add that in quite recent times t
has just been extended in an unexp
class of magneto-electric machines fo
alternate reversal of the polarities su
the different parts of an annular elec
ful magnet, and in the action exerci
wires of the coils passing before it. T
machines of Gramme, of Siemens, of

of De Méritens, which have furnished such marvellous results.

Of these various machines, it is evidently those which call a motor into play that are applicable for electric lighting, for it is in this form that electricity can be obtained under the most economical conditions. These machines will therefore exclusively occupy our attention; but before this we think some indications should be given of the laws regulating induced currents, and of the different causes which concur for their production.

THE DIFFERENT MODES OF GENERATING INDUCED CURRENTS, AND THE LAWS WHICH GOVERN THEM.

Besides the induction effect which we have already explained, there are many other causes capable of developing induced currents. Every action, the effect of which is to diminish or to increase the power of a magnet already acting on an induction coil may give rise to induced currents which will be direct when there is diminution, and inverse when there is increase. This increase may result from the action on the magnetic poles of an armature of soft iron, and diminution will result from the withdrawal of that armature. Again, if the pole of a permanent magnet be passed before an iron core surrounded by a coil, a double action will be produced: 1°, a current which may be termed an *electro-dynamic induction current*, which will result from the successive passage of the spires of the induced coil before the pole of the inducing magnet, and which will be the more energetically developed the more suitable precautions are taken to avoid the hurtful induction to which the parts of the spires behind those directly affected by the magnet are liable; 2°,

a current to which I have given the name of
current, and which results from the inversio
polarities to which the core is successively sub
of the movement of the inducer.* These

---

* In order that the origin of the currents which now pla
part in the new electric generators may be thoroughly unde
examine what takes place when a bar of soft iron surrounde
tizing coil is brought near one of the poles of a permane
instance, near the north pole. At the instant of approach the
duced a first current, a current of magnetization, whose directio
upon which end of the bar is acted upon by the magnetic pole.
is due to the transformation of the bar into a magnet. If the ma
drawn, a current will again be induced in the direction opp
former, and which will correspond with the demagnetization
But if the pole of the magnet be brought near the *middle* of th
will be no current produced, because the bar itself will then for
with a *consequent point*, and the effect of the induction on the
this point will be counteracted by that on the other side. The sa
will ensue if the coil is deprived of the iron core. Now, it follows
principle that, if the iron bar surrounded by its coil be bent so as
ring, neither currents of magetization nor of demagnetization can be
by the approach or recession of the magnet, to what point soever i
directed, for the parts to the right and to the left of the point affected
polarized in the same manner. Nevertheless, if the magnet be
parallel to the axis of the bar, that is to say, circularly about the ring
no longer be the same thing, and a current may be produced, due ne
magnetization nor to demagnetization, but which will, under certai
ditions, last during the whole time the magnet is revolving in the same
tion. This current may be the result of two different and simulta
actions, but in order that it may be manifested it will be necessary f
coil to have a certain arrangement, for even if the induction be produc
a single magnetic pole, the two opposite parts of the ring affected w
always be polarized in a different direction, and would give rise to con
currents. One of these actions is the result of the magnetic disturb
produced in the core itself by the successive inversion of its polaritie
disturbance which must, as I have proved, give rise to a reaction analog
to that observed when an effect of demagnetization is made to follow
effect of magnetization under opposite conditions; and as under such c
ditions the resulting currents have the same direction, and in consequen
of the progressive motion of the inducer they follow each other without
terruption, a continuous current is the upshot, and this changes in directi
only when the direction of the movement of the inducing pole is chang
The other action results from the motion itself of the magnetic induci
system before the spires of the induced coil, or what amounts to the sa
thing, from the motion of these coils before the inducing system. (*See Note*

which are continuous, are manifested during the whole period of the magnet's movement, and their direction depends upon that of this movement, but it always corresponds with a demagnetization current, that is to say, with a current in the same direction as that of the magnetic current of the core affected.* It is these currents which act in the Gramme machines. The other reactions which were first discussed have given birth to magneto-electric machines, of which the best-known forms are those of Dujardin, Breton, Duchenne, Wheatstone, Bréguet, &c.; but as these machines have not produced effects sufficiently powerful to form generators of electric light, we shall say no more about them.

There are yet other sources of induction which have promised to give origin to magneto-electric machines, and of their number is that which has given rise to the *peripolar* induction machine of Le Roux; but these sources are still too feeble to be applied advantageously.

Laws of Induced Currents.—Many experiments made on induced currents have proved:—

1°. That the quantity of electricity put in action in a circuit is proportional, other things being equal, to the intensity of the inducing current and to the length of the induced circuit.

2°. That it is independent of the duration of the inducing action, and varies only with the magnitude of the initial cause of induction.

3°. That the tension of the induced current varies on the contrary with the duration of the inducing action, and increases with the rapidity of the variation of the inducing cause; a circumstance which goes to show that the tension of an induced current is proportional to the algebraic derivative of the function of the time expressing the law of succession of the values of the intensity in the induced current.

---

* For the explanation of these effects see Note A at the end of the book.

he induced wire would be expressed by a quantity variable o doubt with the machines, but which may, with the *Alliance* machines, be six times greater than its true value. It follows hen, that, taking into account this increase of resistance, his work is proportional to the square of the electro-motive force developed, and to the resistance of the external circuit, and is inversely proportional to the square of the total reistance of the circuit, and this leads to the conclusion hat the maximum effect is obtained when the resistance of he external circuit exceeds that of the induced circuit by he quantity with which this last must be increased in order hat Ohm's formula may be applicable to these machines.

We shall not speak of the laws relating to induced currents of different orders, for we shall have to concern ourselves but ittle about these effects in the machines used for electric ighting. But we must carefully study the influence on the nduced currents of the shape, the dimensions, and the composition of the magnetized core, as well as that which results from the speed of the alternate magnetizations and demagnetizations.

If it is considered that the power of electro-magnets is proportional to the diameters of the magnetic cores, and to he square root of their length, it may be supposed that it would be of advantage to make the iron cores of induction apparatus the thickest and the longest possible. But as the alternations of magnetization and demagnetization are produced much more slowly with large iron cores than with small ones, and as again a cylindrical metallic surface allows of the formation of local induced currents which are developed to the prejudice of the induced currents themselves, some middle course had to be sought for, and recourse was had to bundles of iron wires or of juxtaposed thin plates of sheet-ron, the magnetic adherence of which is not sufficiently perfect to be equivalent to a continuous mass of that metal. This means has yielded excellent results, as we shall farther on have occasion to observe.

Experiments on the leng
yet been sufficiently multip
enable a very definite law t
them. Poggendorff, Muller, a
however, observed in a simpl
the inducing action is stronger a
in any other point, and therefor
greatest possible number of spires
this part of the coil, which impli
form of a spindle. This result wil
considered that the middle of a coil
sultant of all the dynamical effects of
of the magnetic core. As to the len
selves, it seems that there is an advai

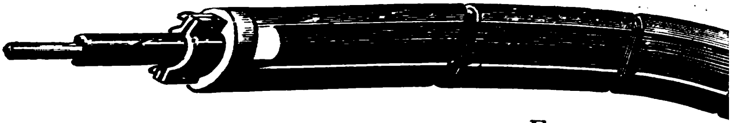


FIG. 13.

rather long to obtain tension, and rather s
quantity. Siemens, however, has contrived a
tion coil entirely different from the ordinary for
given excellent effects. It is represented in F
magnetic core is made of a cylinder of iron, in w
groove is formed longitudinally surrounding the cy
in this the wire of the coil is wound parallel to t
the cylinder, and is bound with bands which preven
yielding to the influence of centrifugal force when the
rotates. The parts of the iron cylinder left uncovere
the polar ends of the coil. The bobbin of course revol
the axis of the cylinder, and in a semi-cylindrical
formed in the iron armature fitted to the two poles of
inducing magnet, as shown in Fig. 14. The two ends of
wire of the coil terminate in a commutator shown at the e

f the axis of the bobbin, on which press two springs conected with the circuit.

When it is wished to use cylindrical cores of iron there is n advantage, in respect to induction, to form them of iron ubes, slit longitudinally, and to put two or three of them ne within the other. In the large machines of the Alliance ompany this plan has been made use of.

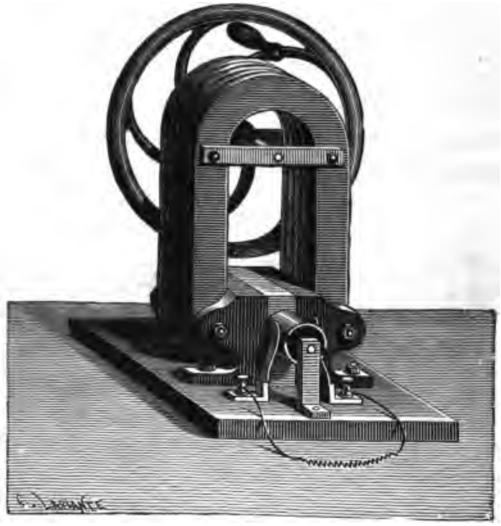


FIG. 14.

As to the more or less advantageous effects of quicker or lower alternations of magnetization and demagnetization, he question is complicated on account of the magnetic nertia of iron. According to the proportionality of the ension of the currents to the *derivative* of the function of the ime, one would suppose that these alternations ought to be s rapid as possible; but the tardiness with which iron is nagnetized and demagnetized much complicates the effect roduced, and it is observed that whilst slow interruptions of the inducer are favourable to the develop of the induced current in Ruhmkorff's co rotation, and, therefore, very rapid alternat tion and demagnetization, are required to mum effect with magneto-electric machines fore, be said that in general a rapid successi tions and demagnetizations increases the tens and allows the magnetic cores to acquire the magnetization. It will be understood by number of successive inducing effects which a furnish, to be under the best conditions, will its construction, and that the more readily organs are able to undergo magnetization and tion, the greater should be its speed.

There are also certain conditions in the relati ment of the induction organs which are more or l able to a high speed; for example, in an ordinary electric machine formed of several induction coils intensity of the sum of all the transmitted currents with the velocity of rotation, but in a less ratio than crease of the velocity. This increase depends on cumstances, that is to say, on the intensity of the itself, and on the greater or less number of coils con for tension. The greater the number of coils arrange tension the less rapidly does the electro-motive forc crease, and this slowness of increase is the greater a intensity of the current is greater.

"It follows from all this," says Le Roux, "that the incre of intensity cost more and more when it is sought to ob them by increase of velocity; for, if theoretically each turn sumes a quantity of work proportional only to the useful e it will finally produce, practically such turn causes the loss certain quantity of work expended on passive resistance of ev kind. Nevertheless, in the calorific applications of electricity is of importance to obtain these high intensities, since the use effect is proportional to their square in a given time; but in

Lontin, Gramme, Siemens, &c. We shall of course begin with the *Alliance* machines, the earliest of all

The Alliance Machines.—The comparatively powerful effects produced by the magneto-electric machines of Pixii and of Clarke at once suggested the idea of using them as economical generators of electricity, and it was supposed that by making them of a large size and driving them with a steam-engine, not only might the cost of electricity, which is so great with batteries, be considerably reduced, but currents of much greater regularity and constancy might be obtained. By the year 1849 Nollet, professor of physics in the military school at Brussels, proposed in fact to construct a Clarke's machine on a large scale, and by introducing into it the improvements which the progress of science and his own experiments had suggested, he invented the machine which is now known as the *Alliance Machine*. Unfortunately his labours were arrested by death, when he was about to see his scheme, not indeed successful, for its success was not to be immediate, but to see it submitted to practical tests. Bold speculators, helped by rich and powerful persons, succeeded indeed in floating a scheme, founded on Nollet's machines, for extracting gas from water. This was a mad notion, but for that very reason it found adherents, and it was the Company then formed which, under the name of *The Alliance*, set up by the year 1855, in buildings belonging to the *Hôtel des Invalides*, the first large magneto-electric machines known in Europe. Of course the results obtained were miserable, to say the least, and in 1856 the Company was compelled to go into liquidation.

It was reorganized some time afterwards, and having appointed Berlioz as its manager, it endeavoured to profit by the considerable materials it had formed. I was then consulted, and indicated to Berlioz the application which he could make of them to the electric light and to electroplating. But for that purpose many improvements had to

be introduced into these machines, and all the e
of the time contributed each a stone to the edifice
Among these improvements there is one by whi
the effect is at once obtained. It was suggested by
at that time professor of natural philosophy at
Centrale, whom I took to see these machines, and
in the suppression of the commutator formerly u
such machines. All these improvements, which
mirably carried out by Van Malderen, the Compa
neer, made it possible, in conjunction with the impr
he himself introduced, to carry the machines to a
perfection which the most sanguine had scarcely h
and which it was thought could not be surpassed. A
for the first time, attention was turned to the avail
the electric light for the illumination of ships and lig
In conjunctfon with Reynaud and Degrand, exp
were thereupon instituted, and shortly afterwards,
it was found possible to illuminate the lighthouse
Hève in this way.

About the same time experiments were made r
the use of the electric light for ships. These exp
did not at first prove entirely successful, owing chie
opposition of the navy. But after a while the impo
the results obtained came to be understood. Fra
led the van in this double path of progress, as she
in the matter of public illumination; but we must
that the civilized world is indebted to the *Alliance* C
and to the enterprise of its intelligent manager B
these beautiful applications of electricity.

Now that we have acknowledged our obligations
pany whose efforts fortune failed to reward, we are
study the constructive details of their machines.

The principle of the *Alliance* Company's mach
resembles that on which Clarke's machine is base
mechanical arrangement is so contrived that the
coils and magnets may be multiplied without incon

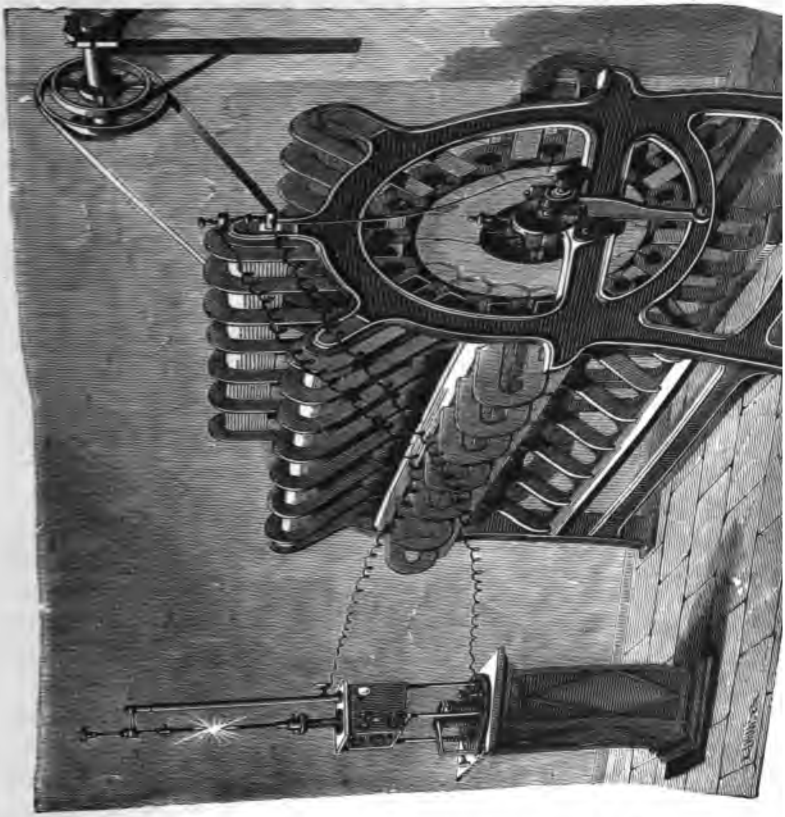
een coils are placed on a bronze wheel provided with able receptacles and fastening-collars by which they are ngly clasped. This arrangement, which for brevity we ll call the *disc*, revolves between two rows of horseshoe gnets, fixed parallel to the plane of the disc on a particu- kind of frame constructed of wood only, at least in the nity of the magnets. Each row contains eight magnets, thus presents sixteen poles at uniform distances apart. is there are as many poles as coils, and when any one of latter is opposite a pole the remaining fifteen are in a position.

)ne machine may have several discs mounted on the same , with several rows of magnets fixed on the same frame. number of discs does not usually exceed six, as the chines would be too long, and it would be difficult to id flexure of the axle and the frame. It should be borne nind that the coils must revolve as close as possible to magnets, but without touching them. At the present e nearly all these machines have only four discs.

ig. 15 shows a general view of a six-disc machine, and . 16 indicates the manner in which each coil E is pre- ted before the poles A, B; B″, A″; *a*, b; *b′*, *a′*, &c., of the erent magnets, which are so placed in the contiguous s that a north pole may be opposite to a south pole in er to polarize in opposite directions the magnetic core of h coil. The ends of the wires of the coils are attached lat pieces of wood fixed on the bronze wheel, and on these coils may be arranged either for tension or for quantity, the elements of an hydro-electric battery. One pole of total current is connected with the axle C, which com- nicates with the frame through the bearings; the other e ends in a metallic collar, D C, concentric with the axle, l insulated from it by wood or ebonite, and these two poles connected with the external circuit by the cast-iron frame the apparatus, and by a friction-spring which, by means of ire, is in communication with a binding screw.

We shall now enter into some details o
machines.

The magnets are, as we have said, of a



and come from the workshops of Allevard; they weigh abo
20 kilogrammes each, and are composed of five or six plat
of tempered steel, fitted to each other by grinding, and he
together by screws; the thickness of each plate is abo

›f larger dimensions, which however yielded results in- · to those just mentioned. Nevertheless, they were ɩ up for the illumination of lighthouses on the English t. It will be seen farther on by the trials made in Eng- itself that of all the machines tried these gave the least ıntageous results, and we shall, therefore, say nothing e about them.

Vilde's Machine.—Soft iron being, by reason of its ater magnetic conductivity, capable of giving a much ater maximum magnetization than the tempered steel of ich permanent magnets are formed, Wilde thought that ›re might be an advantage in employing as inducing organs ›ctro-magnets instead of magnets, and that a small supple- entary magneto-electric machine, actuated by the same otion as the induction machine proper, might be used to agnetize them. Reasoning in this way, he was led to the achine represented in Fig. 17, which was the starting-point r all the machines subsequently designated dynamo-electric achines.

We shall, in fact, soon see that this small supplementary priming machine was unnecessary, provided the whole or part of the induced current were made to traverse the wire the electro-magnets. Nevertheless, Wilde's machine pro- ced very good results, and it was the first machine of all dimensions which was able to generate the electric ht; but unfortunately it required a great speed of rotation. As shown in Fig. 17, this machine is composed of two ·ts, of which the upper one is in a manner a miniature ›y of the other. The former is a Siemens' magneto- ctric machine, with a magnet M of 16 plates, between ose poles, *m n*, turns a Siemens' bobbin *o*, already de- ibed on page 57. This small machine is placed upon an n stage *p*, which serves as a connecting piece to the nches A B of the inducing electro-magnet, formed of iron tes wound round with thick wires, and terminated by the two polar pieces T T, between which the induction coil turns.

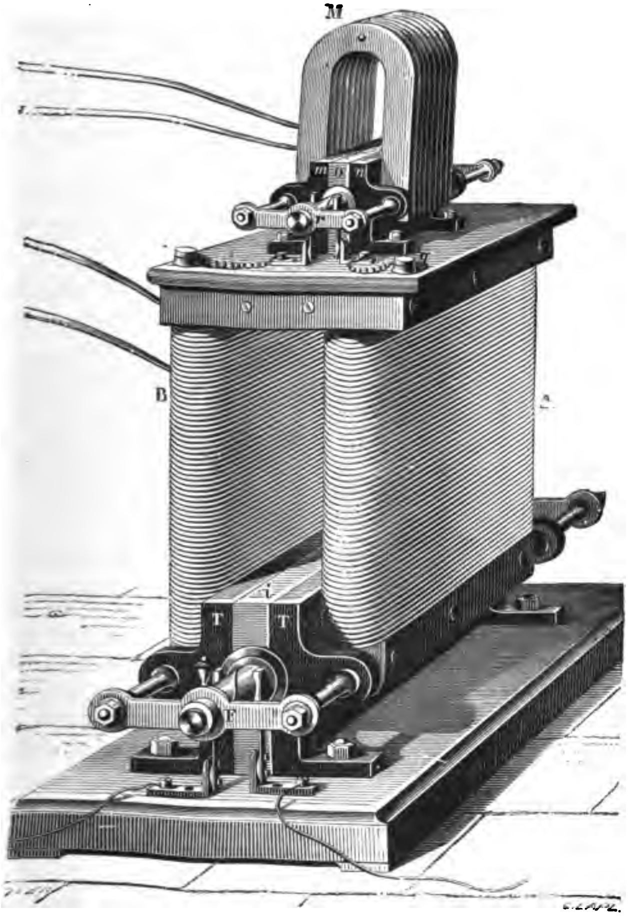


FIG. 17.

As the machine rotates with a speed of from 1,700 to 2,500 revolutions per minute, great heating is thereby occasioned; it was necessary to dispose within the pieces of copper *i*, which separate the polar pieces T T, a channel through which a current of cold water was made to circulate.

The commutator of the apparatus is placed at the end of the axle of the coil, from which the current is collected by means of two springs pressing against it. The bobbin turns also in bearings placed in the cross pieces F, which support it at its extremities, and suitable lubricating apparatus constantly supply the rubbing surfaces with oil.

Under the influence of the movement given to the magneto-electric machine M, the induced current excited in the armature *o* presents itself at the two binding screws *p q*, which are connected with the two ends of the wire of the electro-magnet A B, and the bobbin turning in F supplies the induced currents required to produce the light.

Although this machine has been used in the illumination of one of the Scottish lighthouses, it is to electroplating that it has especially been applied, and at the present time it does not appear to us that it could have competed with any of the new machines. A long description of it is given in our *Exposé des applications de l'électricité tome II.*, p. 226.

Of course the bobbin of the magneto-electric machine revolves with a less velocity than the bobbin of the dynamo-electric machine.

In another arrangement of a machine of this kind—less generally known, doubtless, on account of its greater bulk—Wilde mounted a series of magnetic cores, surrounded by induction coils, on an iron disc revolving in front of powerful electro-magnets; and instead of a second induction machine set apart for the excitation of the inducing electro-magnets, he borrowed some of its own coils from the induced system itself. But two reversing commutators were always required to rectify the two currents, and it is by little more than the suppression of these commutators that the Wallace Farmer and Lontin machines, which we shall presently study, are distinguished from Wilde's. It is curious that this machine did not at once attract more attention, and that it should be

Ladd who benefited, in reputation at l
this combination. Since the lawsuit bro
Ladd, none of the last-named gentlem
been made for illumination, and I am t
exhibited in 1867 is the only one that ha

Ladd's Machine.—A short time after
Wilde's first machine, Wheatstone, thinking
back the effect to its cause, a very minute i
tion communicated to an electro-magnet mig
crease its power indefinitely, conceived the i
the induced current which might be prod
through its magnetizing helix, and he was le
the electro-magnetic system in Wilde's machi
place it by the momentary action of a very
battery. This battery gave rise to an initial m
in the inducing electro-magnet, and leaving in
amount of condensed or residuary magnetism, s
primary cause of the disengagement of electricity
required for more energetic action. From this ar
resulted then a successive increment of the power
ducing electro-magnet, and consequently a strength
the induction current, which could have no other li
the maximum saturation of the electro-magnet and
chanical resistance offered to the motion of the m
This idea, developed in detail by Wheatstone in a
read before the Royal Society of London on the 14th
ruary, 1867, was not long in being improved upon by Si
and Ladd, the former of whom conceived the idea of
pressing the priming battery used by Wheatstone for pu
his apparatus into action, seeing that the mere residual
netism of the iron or the action of terrestrial magne
would suffice to bring about the first induction. I
adopted the plan of dividing the inductive effect betw
two different circuits. The induction was therefore si
taneously effected in two different coils; the current

ced in one of the coils was used to successively augment power of the inducing electro-magnet, while the other l was utilized for the external work. This combination, vever, was, as we have seen, the same as Wilde's. It was irst expected that great advantages would result from this ingement, especially as regards the electric light, for it supposed that a working current so variable in its insity would, in consequence of passing completely through inducing electro-magnet, increase the effects of the variais in the ratio of the simple power to the square, since electo-magnetic forces are proportional to the squares of intensities of the current. But numerous experiments e made by Gramme and Lontin showed that there was itely more advantage gained by causing the whole ined current to traverse the inducing electro-magnet; so at the present day the original arrangement of Siemens been reverted to, and what is still more curious, a rather y controversy regarding this matter has been carried on ontin, who thinks he discovered this kind of action.*

that as it may, Ladd's machine was in 1867 regarded ne of the wonders of the Exhibition, and the small disions of the apparatus were specially a matter for surprise. iat period people were accustomed to the large machines olmes and of the *Alliance Co.*, and a machine of 70 to ntimetres in length, 35 or 40 in breadth, and 20 or 30 pth, capable of producing a relatively intense electric was really a matter for astonishment. Nevertheless, eat velocity of rotation that had to be given to the ne, and the large quantity of heat it generated, soon l that the problem of the economical production of ctric light was far from having been solved in this But the principle of the dynamo-electric system was d as in itself an advance, and we shall see that the

ld appear that Siemens had invented his apparatus simultaneously atstone, and had announced it to the Royal Society of London on day.

machines of Gramme, of Lontin, of Brus Wallace Farmer have all availed themsel

Ladd's machine, represented in Fig. 18 merely one of Wilde's machines turned ho upper part replaced by a second system, bobbin similar to that of the lower part.

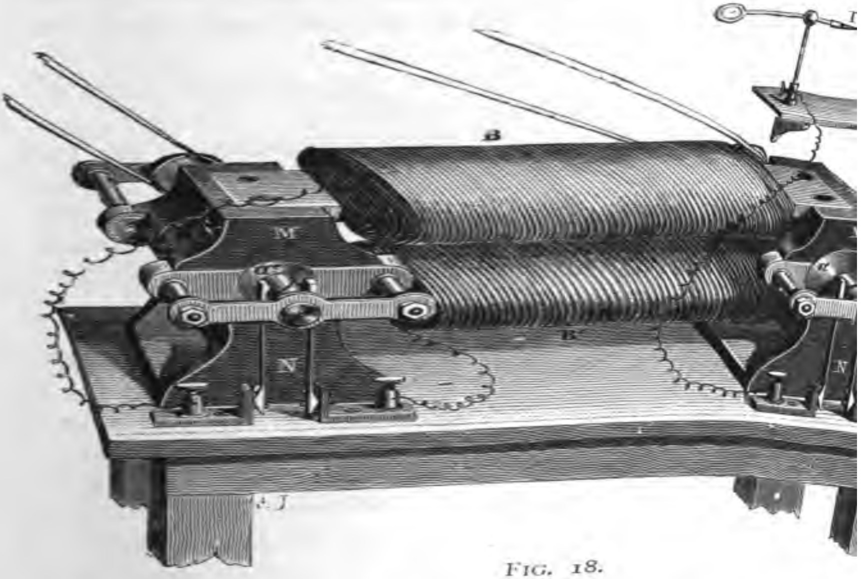


FIG. 18.

system was therefore represented by the two flat horiz coils B B′, and the induced armatures were placed at the a a′, inside of the two iron standards N M, M N, compose two parts forming the polar armatures of the magnetic c B B′. One of the bobbins *a*, less than the other, was inten to excite the inducing electro-magnet; and the other bob *a′* supplied the current for the light. These currents w collected, as in Wilde's machine, by means of the sprin shown in the figure.

[illegible]

In order that the [illegible] while the more powerful effects of the electro-[illegible] which acts like a horseshoe magnet, and that the [illegible] force might not be divided, the two armatures were [illegible] in such a manner that when the iron parts of the [illegible] were opposite the polar armatures, the same parts of [illegible] bottom were in a perpendicular position, and therefore [illegible] position in which leaving the polar armatures which [illegible] acted on them, the direct induced currents were produced. [illegible] Of course the two bobbins were [illegible] set in motion by two belts passing over the same drum.

With the machine of the small dimensions shown at the Exhibition of 1867, the current transmitted externally was equivalent to that from 25 or 30 Bunsen cells. It was able, as we have already stated, to supply—somewhat discontinuously, it is true—one of Foucault's medium-sized electric light regulators.

Gramme's Machine.—The Gramme machine, of which so much has lately been heard, and which has produced the most remarkable results, was originally contrived, so far at least as its general arrangement goes, by Paccinotti, of Pisa, and Worms, of Romilly, as is proved by a description published by the former in the *Nuovo Cimento* for 1860, and by a patent taken out by the latter gentleman on the 3rd March, 1866.*

It was, in fact, only in 1870 that the Gramme machine was constructed; but the principle of the combination of currents in this machine was quite different from that employed in the two which preceded it, and it is for this reason that the one has given unlooked-for results, while the others have remained in the state of ordinary machines. We shall here, therefore, concern ourselves with only the Gramme machine, which is besides the best known at the present day of all dynamo electric machines.

---

* See the description of this machine in my *Exposé des applications de l'électricité*, t. II., p. 222.

[illegible] led to their arrangement in a circle. [illegible] ring was then surrounded transversely by [illegible] covered [illegible] and subjected to the [illegible] magnet, simply magnetic at first, but [illegible] According to the effects ex- [illegible] continuous currents should be obtained [illegible] their direction depending on the [illegible] But it was soon noticed that opposing [illegible] and this led to the division of the [illegible] the ring into different sections, so that these [illegible] like the cells of a battery, and that the [illegible] inducing electro-magnet might be made [illegible] Under these conditions it was in fact [illegible] in the connecting wires of the several [illegible] derivation wires communicating with [illegible] round a circular drum, on which pressed [illegible] collect the current, and these springs, being [illegible] in the position of a derivation between [illegible] joined by their similar poles, would [illegible] into the circuit without the necessity of [illegible] and therefore without the use of commu- [illegible] a very happy idea, and in it is contained Gramme's invention. We shall presently see [illegible] applied to nearly all the new dynamo-electric [illegible] continuous currents, a fact which proves its

produced in the Gramme invention are, how- [illegible] complex, and are connected with several [illegible] principal of which, as we have seen, is the action [illegible] poles on the several spires of the induced [illegible] uction is itself double, for it may result from the coils before these poles, as well as from [illegible] gous to a displacement of these along a [illegible] zed in its different points. Let us first study [illegible] ct, referring to Fig. 20, which theoretically [illegible] utline of a Gramme machine, and let us lower part are traversed by currents in precisely the opposite direction; but as at the two points where the junction of these two opposite currents take place the circuit has a derivation by means of the rubbing pieces F and F′, connected with the external circuit, they flow through this derivation united in quantity.

Let us now examine what happens from the motion of these coils with regard to the magnetism developed in the ring, and in order to fix our ideas, we shall suppose that only one annular electro-magnet turning between the two poles N S of an iron horseshoe magnet is magnetized in such a manner that the system appears to be constituted of two semicircular magnets joined to each other by their similar poles, whence it follows that on the equatorial line, that is to say, on the diameter perpendicular to the line joining the two poles of the inducing magnet, there exist two neutral regions, and it follows also that the magnetic coil is wound from left to right in one side of the ring, and from right to left in the other side. Now let us see what takes place when coils of a short length, such as those previously referred to, are made to move before such a magnetic system, and let us follow, as before, the course of the short coil E, supposing the iron ring to be stationary. In leaving the neutral line on the right to move towards the point S, the coil will be receding from the *resultant* of all the magnetic spires of the right part of the ring corresponding with its neutral line, and there will be developed in it a *direct* current, as in the case in which, without a magnet ring, it is made to approach the pole S. When it has passed the upper part of the ring, it will approach the *resultant* of the magnetic spires of the left part of that ring, and give rise to an inverse current; but on account of the different direction of its winding, this current will traverse the circuit in the same direction as the first current, and it will be only at the neutral line towards the left that these effects will change. The coil will then be found to undergo the same reactions as those we have before by their similar poles. There results in the middle of the system two consequent poles of great power, and it is between these poles, prolonged and curved, that the ring is enclosed, with its axle carrying the current-collectors as seen in Fig. 19.

In the first Gramme machines two rings were used, one being reserved, as in Ladd's system, to excite the electro-magnet. But, as we have already said, this ring had soon to be suppressed, and the induced current in its entirety was made to pass through the electro-magnetic system, by which the effects were considerably increased. Henceforth the machines had but a single ring, but it was made of a large size, and, as shown in Fig. 21, the ring itself, instead of being made of a solid piece of iron, was formed by a bundle of many iron wires, as in the voltaic induction machines.

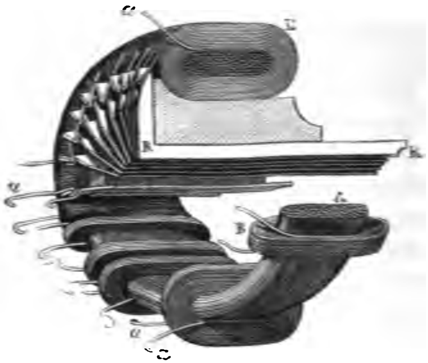


FIG. 21.

Fig. 21 represents a section of this ring, and shows the way in which the different sections of the induced coil are wound upon it. The connecting wires *a a a* of the various sections are, as shown in the upper part of the figure, soldered to the plates R R, which are placed side by side round the axle of rotation, and constitute a kind of drum on which duced in one of the coils was used to successively augment the power of the inducing electro-magnet, while the other coil was utilized for the external work. This combination, however, was, as we have seen, the same as Wilde's. It was at first expected that great advantages would result from this arrangement, especially as regards the electric light, for it was supposed that a working current so variable in its intensity would, in consequence of passing completely through the inducing electro-magnet, increase the effects of the variations in the ratio of the simple power to the square, since the electo-magnetic forces are proportional to the squares of the intensities of the current. But numerous experiments since made by Gramme and Lontin showed that there was infinitely more advantage gained by causing the whole induced current to traverse the inducing electro-magnet; so that at the present day the original arrangement of Siemens has been reverted to, and what is still more curious, a rather lively controversy regarding this matter has been carried on by Lontin, who thinks he discovered this kind of action.*

Be that as it may, Ladd's machine was in 1867 regarded as one of the wonders of the Exhibition, and the small dimensions of the apparatus were specially a matter for surprise. At that period people were accustomed to the large machines of Holmes and of the *Alliance Co.*, and a machine of 70 to 80 centimetres in length, 35 or 40 in breadth, and 20 or 30 in depth, capable of producing a relatively intense electric light, was really a matter for astonishment. Nevertheless, the great velocity of rotation that had to be given to the machine, and the large quantity of heat it generated, soon showed that the problem of the economical production of the electric light was far from having been solved in this way. But the principle of the dynamo-electric system was regarded as in itself an advance, and we shall see that the

---

* It would appear that Siemens had invented his apparatus simultaneously with Wheatstone, and had announced it to the Royal Society of London on the same day.

Sixteen coils are placed on a bronze wheel provided with suitable receptacles and fastening-collars by which they are strongly clasped. This arrangement, which for brevity we shall call the *disc*, revolves between two rows of horseshoe magnets, fixed parallel to the plane of the disc on a particular kind of frame constructed of wood only, at least in the vicinity of the magnets. Each row contains eight magnets, and thus presents sixteen poles at uniform distances apart. Thus there are as many poles as coils, and when any one of the latter is opposite a pole the remaining fifteen are in a like position.

One machine may have several discs mounted on the same axle, with several rows of magnets fixed on the same frame. The number of discs does not usually exceed six, as the machines would be too long, and it would be difficult to avoid flexure of the axle and the frame. It should be borne in mind that the coils must revolve as close as possible to the magnets, but without touching them. At the present time nearly all these machines have only four discs.

Fig. 15 shows a general view of a six-disc machine, and Fig. 16 indicates the manner in which each coil E is presented before the poles A, B; B″, A″; *a*, b; *b*′, *a*′, &c., of the different magnets, which are so placed in the contiguous rows that a north pole may be opposite to a south pole in order to polarize in opposite directions the magnetic core of each coil. The ends of the wires of the coils are attached to flat pieces of wood fixed on the bronze wheel, and on these the coils may be arranged either for tension or for quantity, like the elements of an hydro-electric battery. One pole of the total current is connected with the axle C, which communicates with the frame through the bearings; the other pole ends in a metallic collar, D C, concentric with the axle, and insulated from it by wood or ebonite, and these two poles are connected with the external circuit by the cast-iron frame of the apparatus, and by a friction-spring which, by means of a wire, is in communication with a binding screw.

the induced wire would be expressed by a quantity variable no doubt with the machines, but which may, with the *Alliance* machines, be six times greater than its true value. It follows then, that, taking into account this increase of resistance, this work is proportional to the square of the electro-motive force developed, and to the resistance of the external circuit, and is inversely proportional to the square of the total resistance of the circuit, and this leads to the conclusion that the maximum effect is obtained when the resistance of the external circuit exceeds that of the induced circuit by the quantity with which this last must be increased in order that Ohm's formula may be applicable to these machines.

We shall not speak of the laws relating to induced currents of different orders, for we shall have to concern ourselves but little about these effects in the machines used for electric lighting. But we must carefully study the influence on the induced currents of the shape, the dimensions, and the composition of the magnetized core, as well as that which results from the speed of the alternate magnetizations and demagnetizations.

If it is considered that the power of electro-magnets is proportional to the diameters of the magnetic cores, and to the square root of their length, it may be supposed that it would be of advantage to make the iron cores of induction apparatus the thickest and the longest possible. But as the alternations of magnetization and demagnetization are produced much more slowly with large iron cores than with small ones, and as again a cylindrical metallic surface allows of the formation of local induced currents which are developed to the prejudice of the induced currents themselves, some middle course had to be sought for, and recourse was had to bundles of iron wires or of juxtaposed thin plates of sheet-iron, the magnetic adherence of which is not sufficiently perfect to be equivalent to a continuous mass of that metal. This means has yielded excellent results, as we shall farther on have occasion to observe.

of the axis of the bobbin, on which press two springs connected with the circuit.

When it is wished to use cylindrical cores of iron there is an advantage, in respect to induction, to form them of iron tubes, slit longitudinally, and to put two or three of them one within the other. In the large machines of the Alliance Company this plan has been made use of.

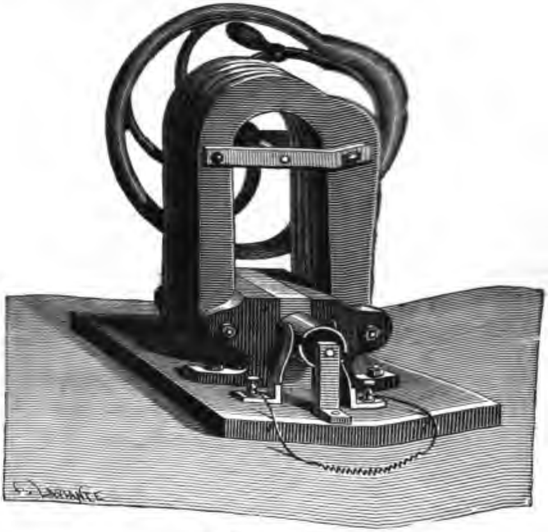


Fig. 14.

As to the more or less advantageous effects of quicker or slower alternations of magnetization and demagnetization, the question is complicated on account of the magnetic inertia of iron. According to the proportionality of the tension of the currents to the *derivative* of the function of the time, one would suppose that these alternations ought to be as rapid as possible; but the tardiness with which iron is magnetized and demagnetized much complicates the effect produced, and it is observed that whilst slow interruptions of chemical applications, for which the effect is proportional to the first power of the intensity, it is advantageous for the economy of motive force not to drive the machine at high speed."

If the increase of speed in magneto-electric machines augments the intensity of the resulting induced currents, on the other hand the increase in the intensity of the currents opposes the rotatory movement. The more frequent separations of parts attracting each other must give the motive power a greater sum of mechanical resistances to overcome; but there is also in the very circumstance of the development of electrical work effected a mechanical reaction, which is the consequence of the transformation of the physical forces.

Everybody knows the beautiful experiment of Foucault's, which consists in making a copper disc revolve between the poles of a powerful electro-magnet. While the magnet is not in action the disc may be turned with any required velocity, but as soon as the electro-magnet comes into action the disc becomes more and more heated, the resistance offered to its rotation increases considerably, and soon becomes so great that the speed of the machine cannot be further increased. The calorific effect produced has therefore necessitated an expenditure of force by giving rise to an increase of resistance, and the measure of that additional mechanical resistance must be the equivalent of the physical action which has caused it. Now an action of this kind must evidenly be produced in magneto-electric machines in rapid rotation, and especially in dynamo-electric machines.

There is yet an interesting question to study, namely, to ascertain the duration of induced currents, the period which elapses between the closing or opening of an inducing circuit and the appearance of the induced current, and how the intensity of the current behaves at the different phases of its appearance. Blaserna and Mouton have made some very interesting researches on this subject, of which we shall indicate the principal results.

According to Blaserna the time which elapses between the

Lontin, Gramme, Siemens, &c. We shall of course begin with the *Alliance* machines, the earliest of all

The Alliance Machines.—The comparatively powerful effects produced by the magneto-electric machines of Pixii and of Clarke at once suggested the idea of using them as economical generators of electricity, and it was supposed that by making them of a large size and driving them with a steam-engine, not only might the cost of electricity, which is so great with batteries, be considerably reduced, but currents of much greater regularity and constancy might be obtained. By the year 1849 Nollet, professor of physics in the military school at Brussels, proposed in fact to construct a Clarke's machine on a large scale, and by introducing into it the improvements which the progress of science and his own experiments had suggested, he invented the machine which is now known as the *Alliance Machine.* Unfortunately his labours were arrested by death, when he was about to see his scheme, not indeed successful, for its success was not to be immediate, but to see it submitted to practical tests. Bold speculators, helped by rich and powerful persons, succeeded indeed in floating a scheme, founded on Nollet's machines, for extracting gas from water. This was a mad notion, but for that very reason it found adherents, and it was the Company then formed which, under the name of *The Alliance*, set up by the year 1855, in buildings belonging to the *Hôtel des Invalides*, the first large magneto-electric machines known in Europe. Of course the results obtained were miserable, to say the least, and in 1856 the Company was compelled to go into liquidation.

It was reorganized some time afterwards, and having appointed Berlioz as its manager, it endeavoured to profit by the considerable materials it had formed. I was then consulted, and indicated to Berlioz the application which he could make of them to the electric light and to electroplating. But for that purpose many improvements had to

Sixteen coils are placed on a bronze wheel provided with suitable receptacles and fastening-collars by which they are strongly clasped. This arrangement, which for brevity we shall call the *disc*, revolves between two rows of horseshoe magnets, fixed parallel to the plane of the disc on a particular kind of frame constructed of wood only, at least in the vicinity of the magnets. Each row contains eight magnets, and thus presents sixteen poles at uniform distances apart. Thus there are as many poles as coils, and when any one of the latter is opposite a pole the remaining fifteen are in a like position.

One machine may have several discs mounted on the same axle, with several rows of magnets fixed on the same frame. The number of discs does not usually exceed six, as the machines would be too long, and it would be difficult to avoid flexure of the axle and the frame. It should be borne in mind that the coils must revolve as close as possible to the magnets, but without touching them. At the present time nearly all these machines have only four discs.

Fig. 15 shows a general view of a six-disc machine, and Fig. 16 indicates the manner in which each coil E is presented before the poles A, B; B″, A″; *a*, b; *b*′, *a*′, &c., of the different magnets, which are so placed in the contiguous rows that a north pole may be opposite to a south pole in order to polarize in opposite directions the magnetic core of each coil. The ends of the wires of the coils are attached to flat pieces of wood fixed on the bronze wheel, and on these the coils may be arranged either for tension or for quantity, like the elements of an hydro-electric battery. One pole of the total current is connected with the axle C, which communicates with the frame through the bearings; the other pole ends in a metallic collar, D C, concentric with the axle, and insulated from it by wood or ebonite, and these two poles are connected with the external circuit by the cast-iron frame of the apparatus, and by a friction-spring which, by means of a wire, is in communication with a binding screw.

1 centimetre. For the sake of perfect uniformity of thickness at their polar extremities, and also for readiness of adjustment, they are provided with soft iron poles. Each plate is magnetized by the ordinary process, and the bundle should support three times its own weight. This magnetization is, moreover, improved rather than otherwise by the action of the machine.

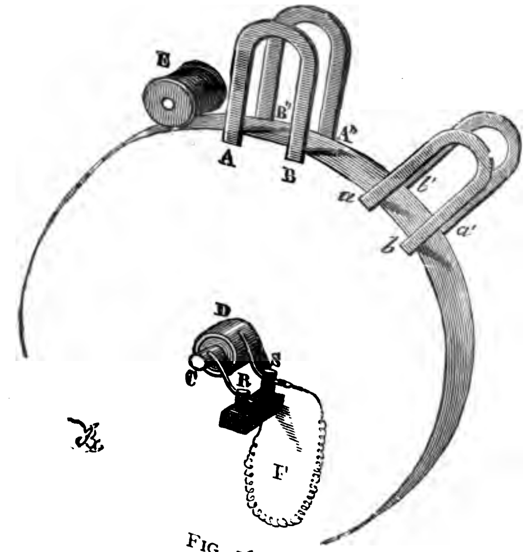


FIG. 16.

The bobbins have undergone many alterations; at the present time they are formed of iron tubes split longitudinally, and have brass caps also divided in order to diminish disadvantageous induction. They are 10 centimetres long and 4 centimetres in diameter, and there are two tubes—one within the other.

The length and action of the wires of these bobbins should depend, as will be readily understood, on the resistance of the external circuit, on the number of bobbins, and on the but of larger dimensions, which however yielded results inferior to those just mentioned. Nevertheless, they were fitted up for the illumination of lighthouses on the English coast. It will be seen farther on by the trials made in England itself that of all the machines tried these gave the least advantageous results, and we shall, therefore, say nothing more about them.

Wilde's Machine.—Soft iron being, by reason of its greater magnetic conductivity, capable of giving a much greater maximum magnetization than the tempered steel of which permanent magnets are formed, Wilde thought that there might be an advantage in employing as inducing organs electro-magnets instead of magnets, and that a small supplementary magneto-electric machine, actuated by the same motion as the induction machine proper, might be used to magnetize them. Reasoning in this way, he was led to the machine represented in Fig. 17, which was the starting-point for all the machines subsequently designated dynamo-electric machines.

We shall, in fact, soon see that this small supplementary or priming machine was unnecessary, provided the whole or a part of the induced current were made to traverse the wire of the electro-magnets. Nevertheless, Wilde's machine produced very good results, and it was the first machine of small dimensions which was able to generate the electric light; but unfortunately it required a great speed of rotation.

As shown in Fig. 17, this machine is composed of two parts, of which the upper one is in a manner a miniature copy of the other. The former is a Siemens' magneto-electric machine, with a magnet M of 16 plates, between whose poles, *m n*, turns a Siemens' bobbin *o*, already described on page 57. This small machine is placed upon an iron stage *p*, which serves as a connecting piece to the branches A B of the inducing electro-magnet, formed of iron plates wound round with thick wires, and terminated by the copper *i*, which separate the polar pieces T T, a channel through which a current of cold water was made to circulate.

The commutator of the apparatus is placed at the end of the axle of the coil, from which the current is collected by means of two springs pressing against it. The bobbin turns also in bearings placed in the cross pieces F, which support it at its extremities, and suitable lubricating apparatus constantly supply the rubbing surfaces with oil.

Under the influence of the movement given to the magneto-electric machine M, the induced current excited in the armature *o* presents itself at the two binding screws *p q*, which are connected with the two ends of the wire of the electro-magnet A B, and the bobbin turning in F supplies the induced currents required to produce the light.

Although this machine has been used in the illumination of one of the Scottish lighthouses, it is to electroplating that it has especially been applied, and at the present time it does not appear to us that it could have competed with any of the new machines. A long description of it is given in our *Exposé des applications de l'électricité tome II.*, p. 226.

Of course the bobbin of the magneto-electric machine revolves with a less velocity than the bobbin of the dynamo-electric machine.

In another arrangement of a machine of this kind—less generally known, doubtless, on account of its greater bulk—Wilde mounted a series of magnetic cores, surrounded by induction coils, on an iron disc revolving in front of powerful electro-magnets; and instead of a second induction machine set apart for the excitation of the inducing electro-magnets, he borrowed some of its own coils from the induced system itself. But two reversing commutators were always required to rectify the two currents, and it is by little more than the suppression of these commutators that the Wallace Farmer and Lontin machines, which we shall presently study, are distinguished from Wilde's. It is curious that this machine did not at once attract more attention, and that it should be duced in one of the coils was used to successively augment the power of the inducing electro-magnet, while the other coil was utilized for the external work. This combination, however, was, as we have seen, the same as Wilde's. It was at first expected that great advantages would result from this arrangement, especially as regards the electric light, for it was supposed that a working current so variable in its intensity would, in consequence of passing completely through the inducing electro-magnet, increase the effects of the variations in the ratio of the simple power to the square, since the electo-magnetic forces are proportional to the squares of the intensities of the current. But numerous experiments since made by Gramme and Lontin showed that there was infinitely more advantage gained by causing the whole induced current to traverse the inducing electro-magnet; so that at the present day the original arrangement of Siemens has been reverted to, and what is still more curious, a rather lively controversy regarding this matter has been carried on by Lontin, who thinks he discovered this kind of action.*

Be that as it may, Ladd's machine was in 1867 regarded as one of the wonders of the Exhibition, and the small dimensions of the apparatus were specially a matter for surprise. At that period people were accustomed to the large machines of Holmes and of the *Alliance Co.*, and a machine of 70 to 80 centimetres in length, 35 or 40 in breadth, and 20 or 30 in depth, capable of producing a relatively intense electric light, was really a matter for astonishment. Nevertheless, the great velocity of rotation that had to be given to the machine, and the large quantity of heat it generated, soon showed that the problem of the economical production of the electric light was far from having been solved in this way. But the principle of the dynamo-electric system was regarded as in itself an advance, and we shall see that the

---

* It would appear that Siemens had invented his apparatus simultaneously with Wheatstone, and had announced it to the Royal Society of London on the same day.

In order that the arrangement might utilize the more powerful effects of the electro-magnet when it acts like a horseshoe magnet, and that the inducing force might not be divided, the two armatures were arranged in such a manner that when the iron parts of the bobbin *a* were opposite the polar armatures, the same parts of the bobbin *a'* were in a perpendicular position, and therefore in that position in which, leaving the polar armatures which had acted on them, the direct induced currents were produced.

Of course the two bobbins were set in motion by two belts passing over the same drum.

With the machine of the small dimensions, shown at the Exhibition of 1867, the current transmitted externally was equivalent to that from 25 or 30 Bunsen cells. It was able as we have already stated, to supply—somewhat discontinuously, it is true—one of Foucault's medium-sized electric light regulators.

Gramme's Machine.—The Gramme machine, of which so much has lately been heard, and which has produced the most remarkable results, was originally contrived, so far at least as its general arrangement goes, by Paccinotti, of Pisa, and Worms, of Romilly, as is proved by a description published by the former in the *Nuovo Cimento* for 1860, and by a patent taken out by the latter gentleman on the 3rd March, 1866.*

It was, in fact, only in 1870 that the Gramme machine was constructed; but the principle of the combination of currents in this machine was quite different from that employed in the two which preceded it, and it is for this reason that the one has given unlooked-for results, while the others have remained in the state of ordinary machines. We shall here, therefore, concern ourselves with only the Gramme machine, which is besides the best known at the present day of all dynamo-electric machines.

* See the description of this machine in my *Exposé des applications de l'électricité, t. II.*, p. 222.

errupted, and this led to their arrangement in a circle. Therefore an iron ring was used, surrounded transversely by a coil which completely covered it, and subjected to the action of an inducing magnet, simply magnetic at first, but afterwards electro-magnetic. According to the effects explained on page 54, continuous currents should be obtained without a commutator, their direction depending on the rotatory movement. But it was soon noticed that opposing actions were produced, and this led to the division of the coil surrounding the ring into different sections, so that these might be combined like the cells of a battery, and that the poles of a powerful inducing electro-magnet might be made to act upon them. Under these conditions it was, in fact possible to place on the connecting wires of the several sections of the coil, derivation wires communicating with plates arranged round a circular drum, on which pressed two springs to collect the current, and these springs, being in this way placed in the position of a derivation between two equal generators joined by their similar poles, would transmit the current into the circuit without the necessity of any inversions, and therefore without the use of commutators. This was a very happy idea, and in it is contained the essence of Gramme's invention. We shall presently see that it has been applied to nearly all the new dynamo-electric machines with continuous currents, a fact which proves its importance.

The effects produced in the Gramme invention are, however, somewhat complex, and are connecteo with several causes, the principal of which, as we have seen, is the action of the magnetic poles on the several spires of the induced coil; but this action is itself double, for it may result from the passage of the coils before these poles, as well as from an action analagous to a displacement of these along a ring differently polarized in its different points. Let us first study the former effect, referring to Fig. 20, which theoretically represents the outline of a Gramme machine, and let us sup-lower part are traversed by currents in precisely the opposite direction; but as at the two points where the junction of these two opposite currents take place the circuit has a derivation by means of the rubbing pieces F and F′, connected with the external circuit, they flow through this derivation united in quantity.

Let us now examine what happens from the motion of these coils with regard to the magnetism developed in the ring, and in order to fix our ideas, we shall suppose that only one annular electro-magnet turning between the two poles N S of an iron horseshoe magnet is magnetized in such a manner that the system appears to be constituted of two semicircular magnets joined to each other by their similar poles, whence it follows that on the equatorial line, that is to say, on the diameter perpendicular to the line joining the two poles of the inducing magnet, there exist two neutral regions, and it follows also that the magnetic coil is wound from left to right in one side of the ring, and from right to left in the other side. Now let us see what takes place when coils of a short length, such as those previously referred to, are made to move before such a magnetic system, and let us follow, as before, the course of the short coil E, supposing the iron ring to be stationary. In leaving the neutral line on the right to move towards the point S, the coil will be receding from the *resultant* of all the magnetic spires of the right part of the ring corresponding with its neutral line, and there will be developed in it a *direct* current, as in the case in which, without a magnet ring, it is made to approach the pole S. When it has passed the upper part of the ring, it will approach the *resultant* of the magnetic spires of the left part of that ring, and give rise to an inverse current; but on account of the different direction of its winding, this current will traverse the circuit in the same direction as the first current, and it will be only at the neutral line towards the left that these effects will change. The coil will then be found to undergo the same reactions as those we have before eir similar poles. There results in the middle of the tem two consequent poles of great power, and it is etween these coils, prolonged and curved, that the ring is enclosed, with its axle carrying the current-collectors as seen in Fig. 19.

In the first Gramme machines two rings were used, one being reserved, as in Ladd's system, to excite the electro-magnet. But, as we have already said, this ring had soon to be suppressed, and the induced current in its entirety

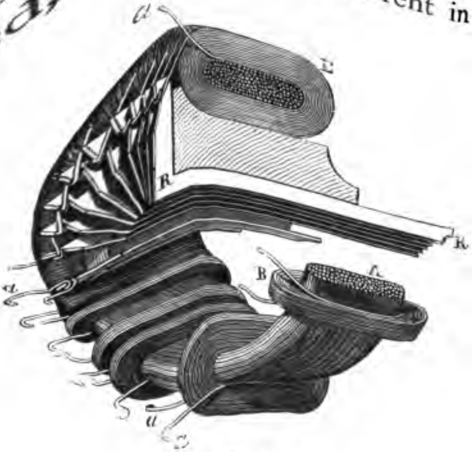


FIG. 21.

was made to pass through the electro-magnetic system, by which the effects were considerably increased. Henceforth the machines had but a single ring, but it was made of a large size, and, as shown in Fig. 21, the ring itself, instead of being made of a solid piece of iron, was formed by a bundle of many iron wires, as in the voltaic induction machines.

Fig. 21 represents a section of this ring, and shows the way in which the different sections of the induced coil are wound upon it. The connecting wires *a a a* of the various sections are, as shown in the upper part of the figure, soldered to the plates R R, which are placed side by side round the axle of rotation, and constitute a kind of drum on which press the two springs of the collector, which are formed by a sort of brush of metallic wires held by supports, as may be observed on the right of the ring in Fig. 19. These plates are, of course, separated by layers of ebonite in order to insulate them electrically. In the figure the inducing electro-magnets are placed horizontally at the top and bottom of the machine, and their polar expansions are seen in the metallic pieces surrounding the ring, serving at the same time as supports to the stems of the rubbing pieces and to the binding screws of the induced circuit.

Gramme machines of the last pattern are little more than 65 centimetres long, 41 centimetres wide, and 50 centimetres high; they weigh 175 kilogrammes, and with 2½ horse-power, giving a speed of revolution of 850 turns per minute, they yield an electric light equal to 2,500 candles or 270 Carcel lamps.

We shall presently see that Gramme has constructed another system of machines to supply currents alternately reversed, and so arranged that the action of the machine may be divided and made to yield currents in several distinct circuits. This arrangement enabled the illumination of the *Avenue de l'Opéra* by Jablochkoff candles to be carried out.

We shall not speak of other forms of the Gramme machine except in the chapter on the applications of the electri light. All the necessary details as regards these may, ho ever, be found in Fontaine's work, entitled *L'Éclairag l'électricité.*

Schuckert has somewhat modified the Gramme mach by employing a flat ring, and by utilizing the magnetism the electro-magnets on the lateral faces of the ring, inst of on the cylindrical part; but we are not sure that alleged increase of power which has been attributed to arrangement is real, and the machine appears to u a copy of the French invention.

We may say the same of a machine constructed in which the ring is so arranged to be subjected

utside; but this machine produces alter-
rents.

hine. — The machine of Siemens and
represented in Fig. 22, which has in com-
nts made in England furnished the best
on nearly the same principle as that of

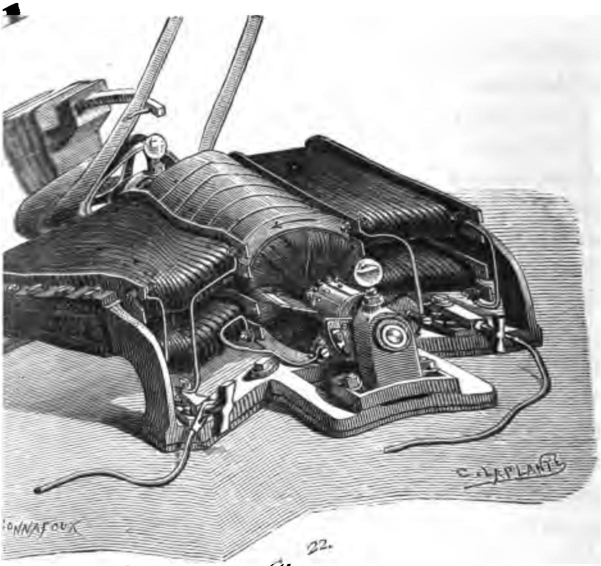


FIG. 22.

ie, although at first sight it appears to be merely a
ation of the elongated coil system of Siemens, that
e already seen taken advantage of in the machines of
nd of Ladd. In this new system the cylindrical coil
iving the induction is of large diameter, and is formed
olving cylinder of copper, on which, parallel to its
wound a certain number of juxtaposed coils like the
galvanometer. These coils are connected for tension,
allic plates join with their connecting wire to a series
arranged round a drum of insulating substance, fixed

on the same axle as the cylinder;
as in the Gramme machine, there pr
metallic wires, which transmit the curre
machine. This cylinder is surrounded by
of a dynamo-electric system through whicl
current is passed, and these semicircular pc
certain number of slits in order to facilitat
tions. The branches of the electro-magne
by plates of iron wider than they are long,
by pieces of iron, which serve as a frame to
form its pillow-blocks.

Finally, inside of the copper cylinder is
the poles of the inducing magnet, an iron
nated by arched plates of the same metal, w
kind of armature for the inducing electro-n
ably reinforce their power.

Under these conditions the induced cur
the dynamical action which we have explai
that is to say, to the movement of the galva
before the inducing poles, only, the two pole
act simultaneously on each coil; and as thi
takes place on the opposite parts of these
current has necessarily a contrary direction in
axis of figure, the two effects concur in th
The change of direction in the currents is, how
in the same manner as in the Gramme machin
of the interpolar space, and it is there that th
of the collector are applied. It will easily b
that currents of polar inversion count for n
machine, and, as I have said, the iron framewo
by reinforcing the electro-magnetic action.
necessary, it may be dispensed with; and t
distinguishes this system from that of Gram
the latter the iron ring, besides being useful
inductive action, serves as a framework for th
the coils.

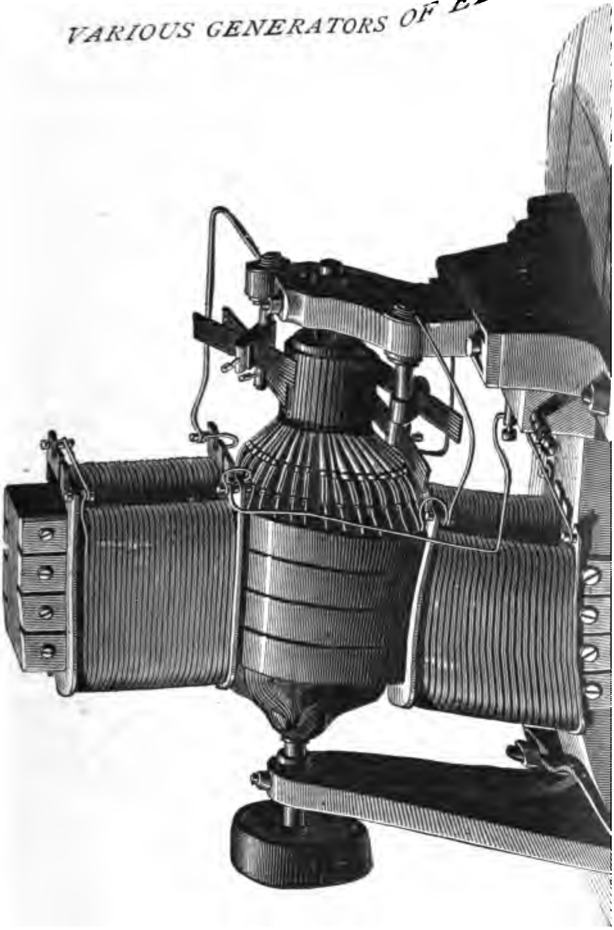
we are now speaking of, the brush rubbers, ctors for the induced current, are carried ance, which by a mere inclination in one ther and by a change of the wires allows nts to be obtained in either direction at

cently arranged a new form of this machine, dimensions than the preceding, resembling chines of the physical laboratory. This is sets in action the machines by the same the currents, that we shall describe farther it is not easy to understand how so small a ich produce effects so powerful.

angement of the apparatus represented in Fig. 23 the same as that we have just described, except that stem is placed vertically instead of horizontally, and nduced coil, instead of being provided inside with a ework of iron serving as armature to the electro-magnetic em, is provided with a cylinder formed of a bundle of es, like the cores of voltaic induction machines. These res, while acting as an armature, at the same time increase e intensity of the inductive effects, as in the machines of uhmkorff and others.

These machines require, however, a high speed of rotation, rom 1,100 to 1,375 turns per minute; but it does not appear that they heat much. The current they supply is sufficiently powerful to light 16 Jablochkoff candles by passing through a machine of the form of Fig. 35 for dividing and reversing the currents.

Siemens has also constructed a form of magneto-electric machine arranged nearly under the same conditions as the preceding, and differing from them only that instead of inducing electro-magnets there are bundles of magnetized bars separated from each, and bound together by strong iron frames as broad as the length of the induced coil. The machine has also a commutator with four rubbers.



De Méritens' Machine.—To judg
electric candles lighted by this machine
the most powerful magneto-electric g
motive force. It can, in fact, with a
ceeding 1 horse-power, maintain 3

ndefinite period, without requiring on the part speed of more than 700 turns per minute, ducing any appreciable heating; but the light se candles does not seem so powerful as that supplied by the Gramme machines; and until res have been given, the relative power of this

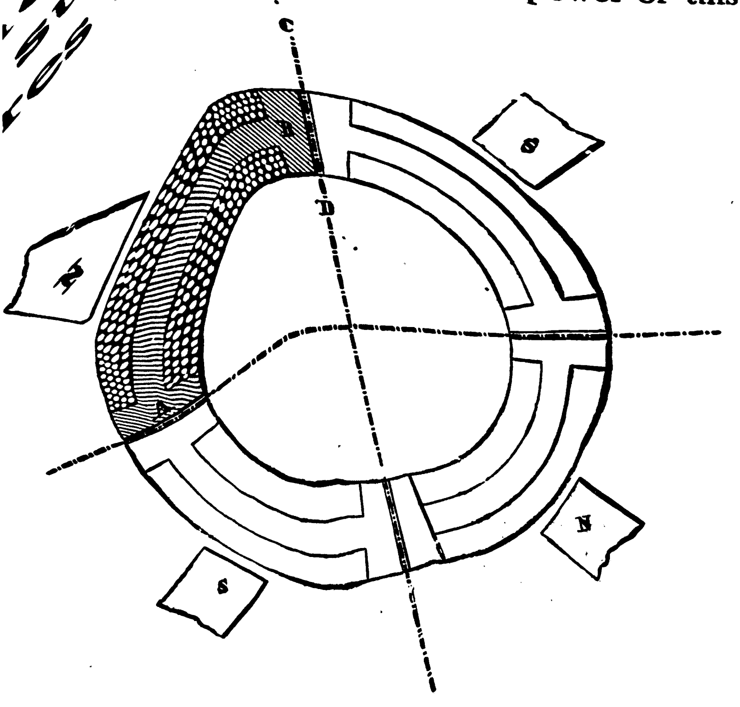


FIG. 24.

generator cannot be definitely estimated. This machine is magneto electric, and, like that of the Alliance, gives reversed currents; but to produce the same effect it requires only 8 Allevard magnets instead of 48, and only a quarter of the motive power. Such, at least, is De Méritens' statement.*

The advantageous effects of this kind of machine result from the fact that the induction currents produced in the ring of the Gramme machines are added to the in the ordinary magneto-electric machines.

---

* The truth is this machine requires 1¼ horse-power.

In order that it may be understood, let us Gramme ring (Fig. 24) divided, for example, in tions, magnetically insulated from each other, an forming four curved electro-magnets placed end t us imagine that the iron core of each of these sec minated at its two extremities by a piece of iron, ing an expansion of its poles; and let us suppo these pieces, connected by means of a piece of cc constitute a solid ring, round which are placed the i magnets, N S N S, with their poles alternating. examine what will happen when this ring complete movement on itself; and let us first observe the e will result, for example, from the approach of the e pole B, as when moving from left to right it appro At this moment there will be developed in the magnetic coil of A B an induced current of magnetiza in Clarke's machine. This current will be instanta and in the reverse direction from Ampère's particul rents of the inducing magnet. It will be very energet account of the nearness of B to the pole N; but the r advancing sets up between the pole N and the core series of magnetic displacements which will give rise to a currents of reversed polarity showing themselves from A. These currents will be direct, as compared with the ticular current of N, but they are not instantaneous, an on increasing in energy from B to A. To these are at same time united the currents of dynamical induction re ing from the passage of the spires of the coil before the N. When A leaves N a current of demagnetization is duced equal in strength to, and in the same direction as induction current resulting from the approach of the ex sion B to the pole N. The effect is, in fact, then prod at the other end of the magnetic core, and the coil is sented to the inductive action in the reverse way.

se induced currents by the fact of the approach val of the expansions B and A. Direct induced ing the passage of the length of core A B before

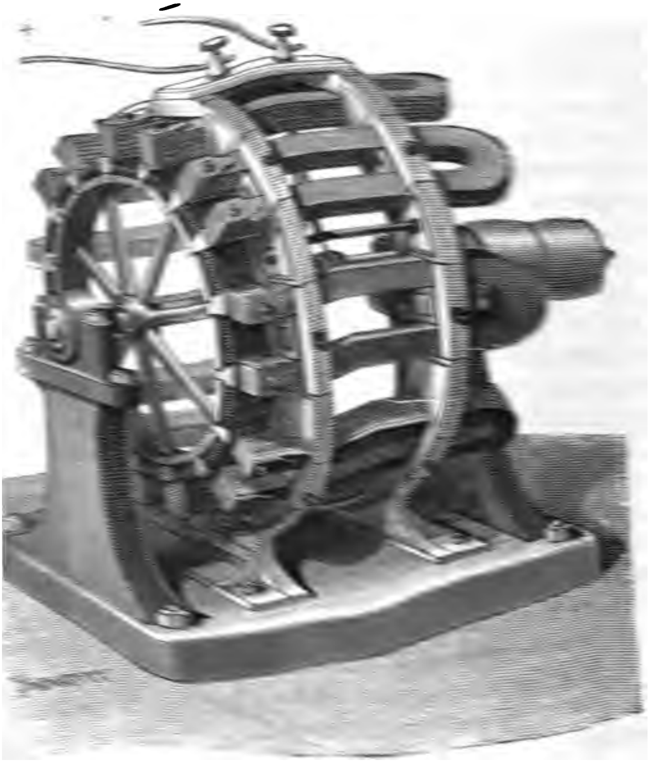


FIG. 38.

a magnetic pole, and direct induced currents resulting from the passage of the spaces before A. All the causes of induction are therefore united in this combination.

It will be observed that the action which we have just scribed in a single section of the ring may take place simultaneously in all the sections and that there are also added

currents resulting from the lateral reaction
B on the neighbouring poles.

In order to increase the inductive effec
forms the core A B and its adjuncts A and B
iron, cut by the punching machine, as show
and bound together in a bundle to the numb
having a thickness of 1 millimetre. The wir
are, moreover, connected in such a manner th

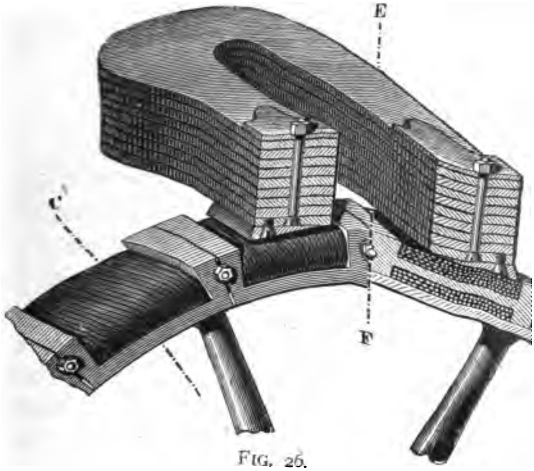


FIG. 26.

currents may be joined for tension, for quantity, or in a
according to the conditions of their application.

We have in the theoretical figure supposed that on
sections are given, but in reality there are a greater nu
and in the form of the machine referred to (shown in Fi
sixteen may be observed. These are mounted on a b
wheel turning on the axle of the motor.

Round about this wheel are planted the inducing mag
firmly fixed on two bronze frameworks, in which the
placed horizontally. Fig. 26 shows the manner in whic
several elements are mounted.

By a little consideration of the way in which the induced ring is arranged it will be easily seen that it is placed under the best possible constructive conditions. In fact, as each section is separate, it may be removed without disturbing the rest, and therefore the wire may be wound without any difficulty. Those who are acquainted with the difficulties of winding the wires on the Gramme ring will readily appreciate this advantage. In another way the building up of the core by juxtaposed laminæ, which may be punched out at one stroke, is an enormous advantage, for this system dispenses with the precision necessary in the construction of these rings, which it is always difficult to keep quite round. Finally, there is neither commutator nor collector in the machine, and therefore there is no loss of current.

We have seen that the currents supplied by this machine are able to light three or four Jablochkoff candles; but they are also able to light regulators, and in this case the carbons may be separated to the extent of 5 centimetres without extinguishing the light. These results are certainly important.

According to an interesting article by Demoget, in the journal *La Lumière Électrique* of the 15th July, 1879, it would appear that the principle of the above-named machine was discovered long before De Méritens, and that as early as the year 1872 he had constructed a very similar machine, which was described in a sealed packet deposited at the *Académie des Sciences* at the meeting of the 20th January, 1875, and that this machine had yielded remarkable results. Drawings of the machine are given in the article we are referring to, but on inspecting them it appears to us that the electro-magnets of the induced ring were not insulated from each other by non-magnetic substances, and in this consists one of the great advantages of De Méritens' machine.

Wallace Former's Machine.—This machine, not previously known in Europe, suddenly acquired some notoriety in consequence of the panic on the Stock Exchange occasioned by the *soi-disant* wonderful discovery in which was to abolish gas and its applications this occasion Edison mentioned the famou machine of Wallace Farmer, which was to su

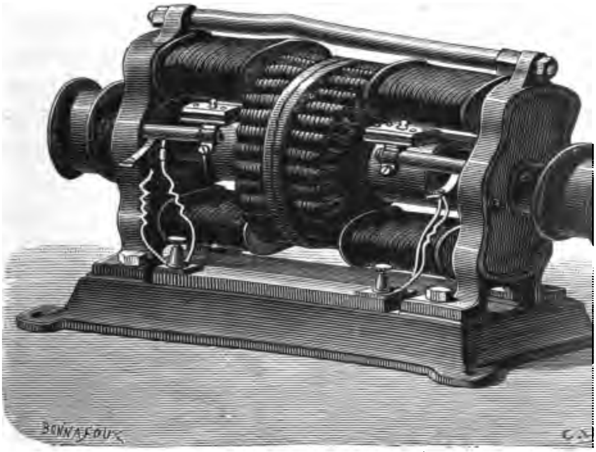


FIG. 27.

of electricity, and everybody was eagerly seeking something of this new wonder. Now, a Report issu Committee appointed by the Franklin Institute in A for a comparative examination of the various mach light, has quite recently opportunely satisfied the cu the public by giving not only a description of this m and of that of Brush, also previously unknown, the numerical results of the experiments undertake Committee, and even the verdict of the Committee spite of the much more favourable results yielde Gramme, pronounced in favour of the American n We shall, however, have occasion to return to thes tions.

Wallace Farmer's machine, which is represente 27, is, in fact, nothing more than a reproduction o machine, already spoken of, and of Lontin's ı is based on the same principle. ıf a large iron disc, provided on both sides with aight electro-magnets, and turning between the ı large electro-magnets with flat branches, having y poles opposite each other. The somewhat :oils are connected together for tension on each e revolving disc, and the connecting wires are in cation with a collector placed on the axle of rotaın the Gramme system, so as to avoid a reversing commutator. This arrangement, in which there is absolutely no novelty, is shown in Fig. 28.

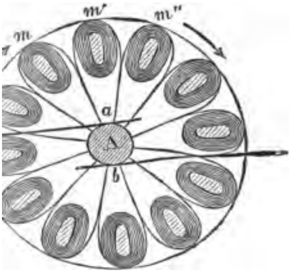


FIG. 28.

It will be perceived that by this arrangement the machine is double, and that each of its parts might act independently; but practically the electrical communi- ıs are so contrived that the currents evolved are united for quantity or for tension through the whole circuit. ıventor believes that heating effects are avoided by the uncovered surface presented by the revolving disc; ıe Committee pointed out that this advantage is purd at the expense of the great resistance which the air to the motion of the machine; and further, it may be ɔy the experiments performed before the Committee ıe machine was heated sufficiently to melt sealing-wax.

ısh's Machine.—Brush's machine, represented in , is one of those experimented with by the Committee Franklin Institute, and it was, in fact, the one to which lm of superiority was awarded. In its principle this

machine much resembles that of De Méri
it is less skilfully put together, and reminds m
attempts made by the last-named gentleman.

This machine consists of a Gramme ring; the co
only eight in number, are separated by rather larg
filled up with pieces of iron. This ring revolve
between the expanded poles of two oblong horsesl
magnets, having the poles of the same name
each other. In this way the two halves of the ri

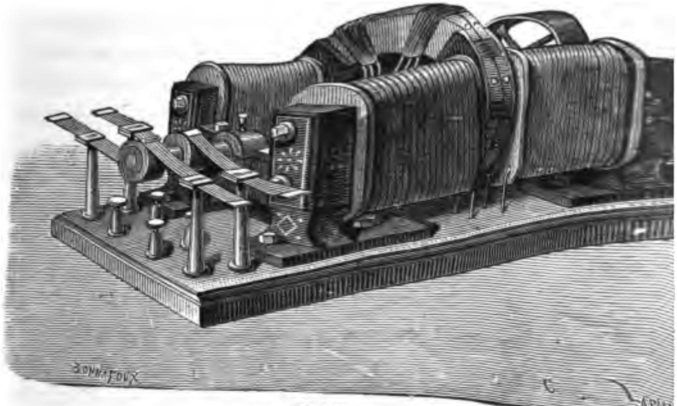


FIG. 29.

surrounded by these poles are polarized uniformly, the
south, the other north; and as with this arrangement
nately reversed currents are produced, as in De Méri
machines, and as snch currents are unsuitable for the
netization of inducing magnets in dynamo-electric machi
it is necessary to put the coils of the revolving ring in c
munication with a reversing commutator, for which four r
bers are required. These rubbers, which are shown in
figure to the right and left at the front, are constructed, as
the Gramme machines, of bundles of wires arranged lik
brush. Fig. 30 indicates the manner in which the wires
the coils are connected with each other and with the c

The opposite coils *b d* are, it will be seen, ered, but these connections are shown in the one pair of coils. In order to place the com- ond position, the ends of the wires are made a hollow axle to reach the projecting parts. tor, A B, is put together in such a manner of coils are always in communication with the machine, and the remaining pair has its ced in the place of the neutral line of the

utator itself is made of plates of copper, *a c*, fixed on rings of insulating matter and shaped as in ordinary apparatus of this kind.

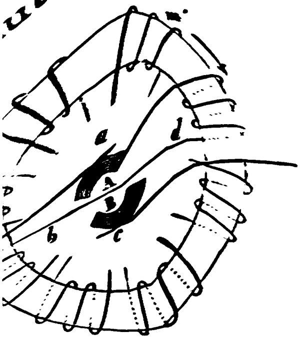


FIG. 30.

The Committee points out that by reason of the iron surfaces which separate the coils being exposed, the ring of this machine is able the more readily to part with its heat, which seldom rises e 120° Fahrenheit, in spite of its very great velocity otation. The machine is blamed, however, for its r loud noise, which is attributed to the resistance of ir, but which is nothing but the sounds due to the alterns of magnetization and demagnetization in the portions e ring. These effects are produced also in De Méritens' in Lontin's machines, and, what is still more curious, ounds are repeated by the Jablochkoff candles placed e circuit of these machines. This effect is connected he electro-telephonic transmissions, which are explained r work on the telephone.

another form of the machine there are two commucorresponding with the two systems formed of the odd and the even coils. "By this means," says t the Committee, "the circuits may be combin transmit currents of more or less intensity, varyi to 120 volts, or so as to divide the currents be circuits, each supplying an electric light."

We may point out that, under these circumst Brush machine is inferior to that of De Mériter cause the iron ring being continuous, the electr currents produced by the approach and withdra magnetic poles lose their energy, as De Méritens his earliest experiments; 2°, because the induced gain much when the magnetic cores are formed of pieces of iron bound together in bundles; 3°, be presence of a reversing commutator occasions mu current.

The Brush machine has recently been applied wit to the illumination of the Park, at the city of Clev America, and if the newspapers of that city may be it has, in conjunction with the electric lamps of inventor, an advantage in economy over the systems England and in France in the proportion of 20 to machine required only 11 horse-power to supply 1 having the luminous intensity of 200 Carcel lamps. believe these accounts are much exaggerated, inas these 12 lights imply a machine for division, whi described by the newspapers we allude to, and whic appear to be confounded with that spoken of above

Bürgin's Machine.—Bürgin, struck like De with the loss of action in the Gramme ring, resulti the withdrawal of the iron core from the inducing p sought to cause its approach by making it pass o coils at longer or shorter intervals. In order to ac this he formed this ring of six separate rings mounted to each other on the same axle, and each having fo netic core a square frame of iron wires (Fig. 31) on ich are wound the induced coils. These coils are d to the shape of a spindle with a curvature so calculated that the four angular parts of the cores are nearly on a with the external spires of these different coils, and fore are able to pass the inducing poles at a very small ce. The frames are also so arranged that the angular uncovered parts of the cores retire from each other so as esent themselves conformably to a spire of a coil. It follows that the magnetizing actions are produced successively, that the currents due to these actions, as well as to that between the wires of the coils, are always of the same intensity in the different phases of each revolution of the ring. The induced coils are, moreover, wound in directions alternately reversed, in order to obtain currents in the same direction in each half of the ring. Finally, these coils are joined to a collector exactly in the same way as in Gramme's and in Siemens' machines, and this arrangement allows continuous currents to be obtained.

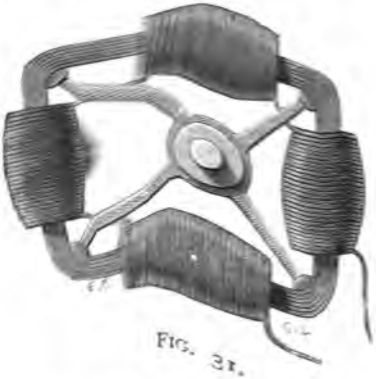


FIG. 21.

The inducer has also the same arrangement as that of the Siemens machines, and the induced current traverses it in its entirety as in those machines.

Experiments made in my presence at Geneva, in the workshops of Turetini, who is the maker of these machines, showed that they have for a given velocity exactly the same luminous power as the ordinary form of Gramme machines, but they have the advantage of becoming very much less heated. In fact, it may be said that they are hardly heated at all. As regards construction, they also present some advantages; thus, for instance, the uncovered parts of the magnetic cores give the of rotation with precisi Gramme ring. In short promising machine.

Trouve's Machine. dynamo-electric machine: ciple as the preceding ma inducing magnets on the contact of the magnetic p that which Larmangeat h electro-motor with electro-

In one of these apparat straight electro-magnet, m with a core provided with electro-magnets of Nicklè ends of a certain numbe arranged in a circle, with t in contact with the expan magnet, and each giving ri reaching a commutator, tr at once the working and t ment is entirely the same motor.

In another form of the on a large scale, the induc just mentioned, but it is magnets placed parallel are thick enough to have similar to those of the axle of iron, and coils so fied by the inducing electr the induced and inducing system in which the mo always in contact, and th power.

ittle consideration of the way in which the induced rranged it will be easily seen that it is placed under t possible constructive conditions. In fact, as each is separate, it may be removed without disturbing the d therefore the wire may be wound without any diffi-

Those who are acquainted with the difficulties of g the wires on the Gramme ring will readily appreciate dvantage. In another way the building up of the core xtaposed laminæ, which may be punched out at one e, is an enormous advantage, for this system dispenses the precision necessary in the construction of these rings, h it is always difficult to keep quite round. Finally, there ither commutator nor collector in the machine, and there- there is no loss of current.

Ve have seen that the currents supplied by this machine able to light three or four Jablochkoff candles; but they also able to light regulators, and in this case the carbons y be separated to the extent of 5 centimetres without tinguishing the light. These results are certainly important.

According to an interesting article by Demoget, in the urnal *La Lumière Électrique* of the 15th July, 1879, it would ppear that the principle of the above-named machine was iscovered long before De Méritens, and that as early as the ear 1872 he had constructed a very similar machine, which was described in a sealed packet deposited at the *Académie des Sciences* at the meeting of the 20th January, 1875, and that this machine had yielded remarkable results. Drawings of the machine are given in the article we are referring to, but on inspecting them it appears to us that the electro-magnets of the induced ring were not insulated from each other by non-magnetic substances, and in this consists one of the great advantages of De Méritens' machine.

Wallace Former's Machine.—This machine, not previously known in Europe, suddenly acquired some notoriety in consequence of the panic on the Stock Exchange occasioned by the *soi-disant* wonderful discove which was to abolish gas and its applicat this occasion Edison mentioned the fa machine of Wallace Farmer, which was t

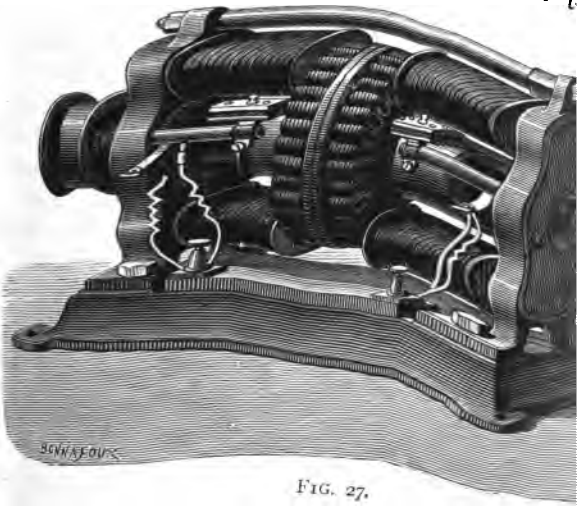


Fig. 27.

of electricity, and everybody was eagerly seeking something of this new wonder. Now, a Report iss Committee appointed by the Franklin Institute in for a comparative examination of the various mach light, has quite recently opportunely satisfied the curi the public by giving not only a description of this m and of that of Brush, also previously unknown, bu the numerical results of the experiments undertaken Committee, and even the verdict of the Committee, w spite of the much more favourable results yielded b Gramme, pronounced in favour of the American mach We shall, however, have occasion to return to these es tions.

Wallace Farmer's machine, which is represented in 27, is, in fact, nothing more than a reproduction on a l scale of Wilde's machine, already spoken of, and of Lontin's machine, which is based on the same principle.

It consists of a large iron disc, provided on both sides with crowns of straight electro-magnets, and turning between the poles of two large electro-magnets with flat branches, having the contrary poles opposite each other. The somewhat flattened coils are connected together for tension on each side of the revolving disc, and the connecting wires are in communication with a collector placed on the axle of rotation, as in the Gramme system, so as to avoid a reversing commutator. This arrangement, in which there is absolutely no novelty, is shown in Fig. 28.

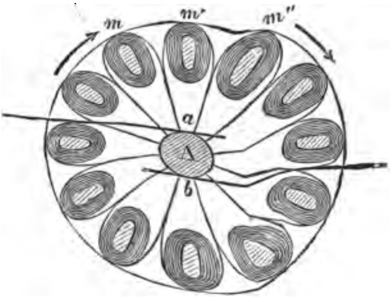


FIG. 28.

It will be perceived that by this arrangement the machine is double, and that each of its parts might act independently; but practically the electrical communications are so contrived that the currents evolved are united either for quantity or for tension through the whole circuit. The inventor believes that heating effects are avoided by the large uncovered surface presented by the revolving disc; but the Committee pointed out that this advantage is purchased at the expense of the great resistance which the air offers to the motion of the machine; and further, it may be seen by the experiments performed before the Committee that the machine was heated sufficiently to melt sealing-wax.

Brush's Machine.—Brush's machine, represented in Fig. 29, is one of those experimented with by the Committee of the Franklin Institute, and it was, in fact, the one to which the palm of superiority was awarded. In its principle this

machine much resembles that of De
it is less skilfully put together, and remin
attempts made by the last-named gentlema

This machine consists of a Gramme ring, t
only eight in number, are separated by rathe
filled up with pieces of iron. This ring re
between the expanded poles of two oblong ho
magnets, having the poles of the same na
each other. In this way the two halves of th

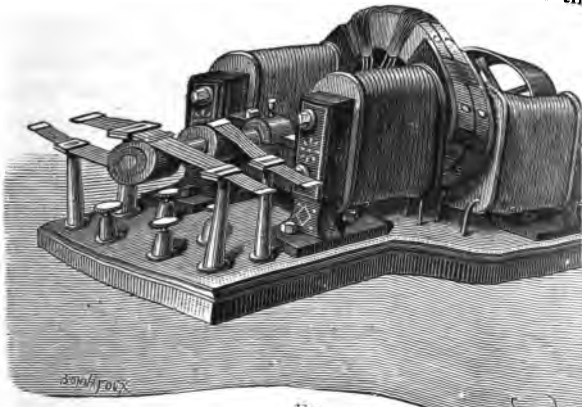


FIG. 29.

surrounded by these poles are polarized uniformly,
south, the other north; and as with this arrangeme
nately reversed currents are produced, as in De M
machines, and as such currents are unsuitable for th
netization of inducing magnets in dynamo-electric ma
it is necessary to put the coils of the revolving ring i
munication with a reversing commutator, for which fou
bers are required. These rubbers, which are shown i
figure to the right and left at the front, are constructed,
the Gramme machines, of bundles of wires arranged
brush. *Fig.* 30 indicates the manner in which the wir
the coils are connected with each other and with the

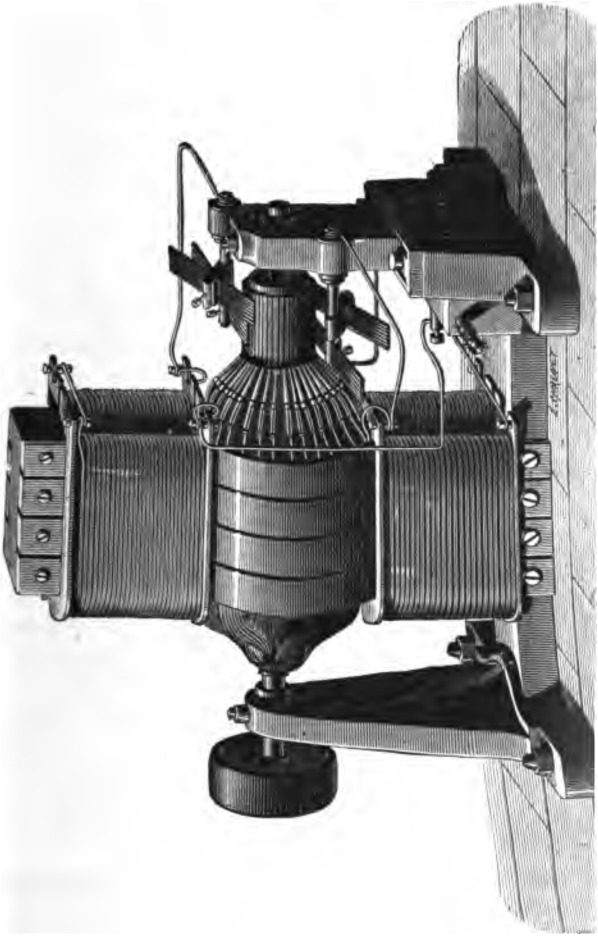
ıachine we are now speaking of, the brush rubbers, as collectors for the induced current, are carried d of balance, which by a mere inclination in one ı or the other and by a change of the wires allows uced currents to be obtained in either direction at e.

nens has recently arranged a new form of this machine, ch smaller dimensions than the preceding, resembling duction machines of the physical laboratory. This is orm which sets in action the machines by the same er for reversing the currents, that we shall describe farther and in which it is not easy to understand how so small a chine can produce effects so powerful.

The arrangement of the apparatus represented in Fig. 23 nearly the same as that we have just described, except that ıe system is placed vertically instead of horizontally, and he induced coil, instead of being provided inside with a ramework of iron serving as armature to the electro-magnetic system, is provided with a cylinder formed of a bundle of wires, like the cores of voltaic induction machines. These wires, while acting as an armature, at the same time increase the intensity of the inductive effects, as in the machines of Ruhmkorff and others.

These machines require, however, a high speed of rotation, from 1,100 to 1,375 turns per minute; but it does not appear that they heat much. The current they supply is sufficiently powerful to light 16 Jablochkoff candles by passing through a machine of the form of Fig. 35 for dividing and reversing the currents.

Siemens has also constructed a form of magneto-electric machine arranged nearly under the same conditions as the preceding, and differing from them only that instead of inducing electro-magnets there are bundles of magnetized bars separated from each, and bound together by strong iron frames as broad as the length of the induced coil. The machine has also a commutator with four rubbers.



De Méritens' Machine.—To judge by the
electric candles lighted by this machine, it might
the most powerful magneto-electric generator w
motive force. It can, in fact, with a motive fo
ceeding 1 horse-power, maintain 3 Jablochk

efinite period, without requiring on the part speed of more than 700 turns per minute, ducing any appreciable heating; but the light se candles does not seem so powerful as that supplied by the Gramme machines; and until es have been given, the relative power of this

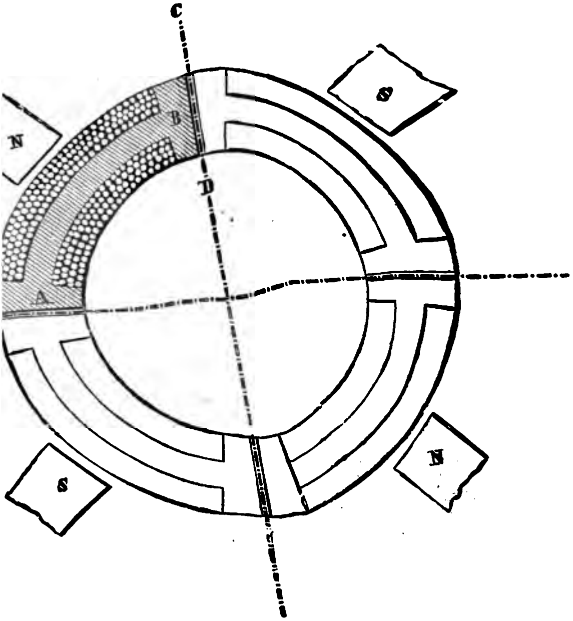


FIG. 24.

tor cannot be definitely estimated. This machine is to electric, and, like that of the Alliance, gives reversed ts; but to produce the same effect it requires only vard magnets instead of 48, and only a quarter of the e power. Such, at least, is De Méritens' statement.* e advantageous effects of this kind of machine result the fact that the induction currents produced in the

---

* The truth is this machine requires 1¼ horse-power.

ring of the Gramme machines are add
in the ordinary magneto-electric machin

In order that it may be understoo
Gramme ring (Fig. 24) divided, for exa
tions, magnetically insulated from each o
forming four curved electro-magnets plac
us imagine that the iron core of each of t
minated at its two extremities by a piece
ing an expansion of its poles; and let u
these pieces, connected by means of a pie
constitute a solid ring, round which are plac
magnets, N S N S, with their poles alter
examine what will happen when this ring c
movement on itself; and let us first observ
will result, for example, from the approach c
pole B, as when moving from left to right i
At this moment there will be developed
magnetic coil of A B an induced current of m
in Clarke's machine. This current will be
and in the reverse direction from Ampère's
rents of the inducing magnet. It will be ver
account of the nearness of B to the pole N; b
advancing sets up between the pole N and
series of magnetic displacements which will give
currents of reversed polarity showing themsel
A. These currents will be direct, as compare
ticular current of N, but they are not instanta
on increasing in energy from B to A. To th
same time united the currents of dynamical in
ing from the passage of the spires of the coil b
N. When A leaves N a current of demagneti
duced equal in strength to, and in the same di
induction current resulting from the approach
sion B to the pole N. The effect is, in fact, t
at the other end of the magnetic core, and t
sented to the inductive action in the reverse

induced currents by the fact of the approach of the expansions B and A, direct induced ; the passage of the length of core A B before

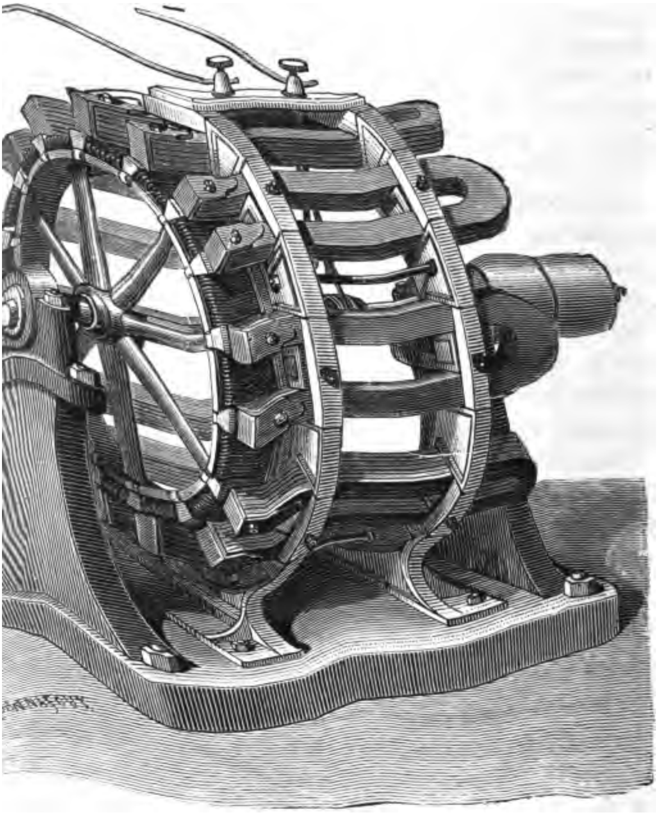


FIG. 25.

agnetic pole, and direct induced currents resulting from assage of the spires before N. All the causes of induc- re therefore united in this combination.

will be observed that the action which we have just d in a single section of the ring may take place simul- isly in all the others, and that there are also added

currents resulting from the lateral reaction of t
B on the neighbouring poles.

In order to increase the inductive effects, L
forms the core A B and its adjuncts A and B of th
iron, cut by the punching machine, as shown on
and bound together in a bundle to the number of f
having a thickness of 1 millimetre. The wires of t
are, moreover, connected in such a manner that the i

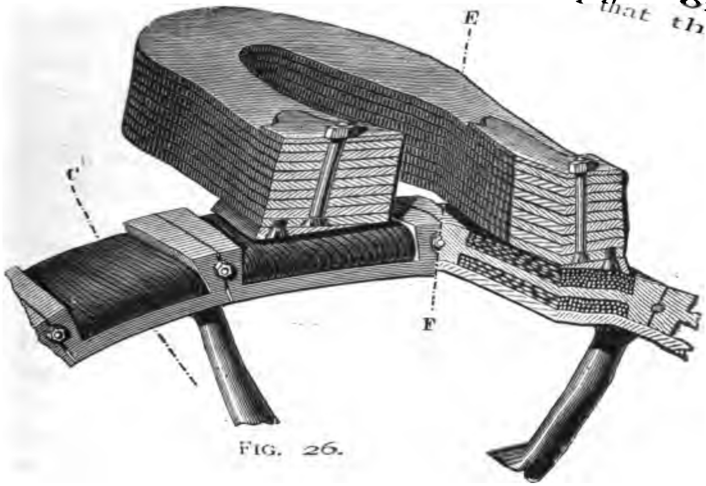


FIG. 26.

currents may be joined for tension, for quantity, or in a series, according to the conditions of their application.

We have in the theoretical figure supposed that only four sections are given, but in reality there are a greater number, and in the form of the machine referred to (shown in Fig. 25) sixteen may be observed. These are mounted on a bronze wheel turning on the axle of the motor.

Round about this wheel are planted the inducing magnets, firmly fixed on two bronze frameworks, in which they are placed horizontally. Fig. 26 shows the manner in which the several elements are mounted.

on of the way in which the induced
e easily seen that it is placed under
ructive conditions. In fact, as each
ay be removed without disturbing the
wire may be wound without any diffi-
re acquainted with the difficulties of
the Gramme ring will readily appreciate
another way the building up of the core
æ, which may be punched out at one
ous advantage, for this system dispenses
ecessary in the construction of these rings,
ifficult to keep quite round. Finally, there
ator nor collector in the machine, and there-
ss of current.
that the currents supplied by this machine
three or four Jablochkoff candles; but they
light regulators, and in this case the carbons
ted to the extent of 5 centimetres without
he light. These results are certainly important.
to an interesting article by Demoget, in the
mière Électrique of the 15th July, 1879, it would
he principle of the above-named machine was
ng before De Méritens, and that as early as the
had constructed a very similar machine, which
l in a sealed packet deposited at the *Académie*
t the meeting of the 20th January, 1875, and
hine had yielded remarkable results. Drawings
ne are given in the article we are referring to,
ecting them it appears to us that the electro-
the induced ring were not insulated from each
-magnetic substances, and in this consists one
advantages of De Méritens' machine.

Former's Machine.—This machine, not pre-
n in Europe, suddenly acquired some notoriety
ce of the panic on the Stock Exchange occa-

sioned by the *soi-disant* wonderful discovery mad
which was to abolish gas and its applications for
this occasion Edison mentioned the famous ge
machine of Wallace Farmer, which was to supply

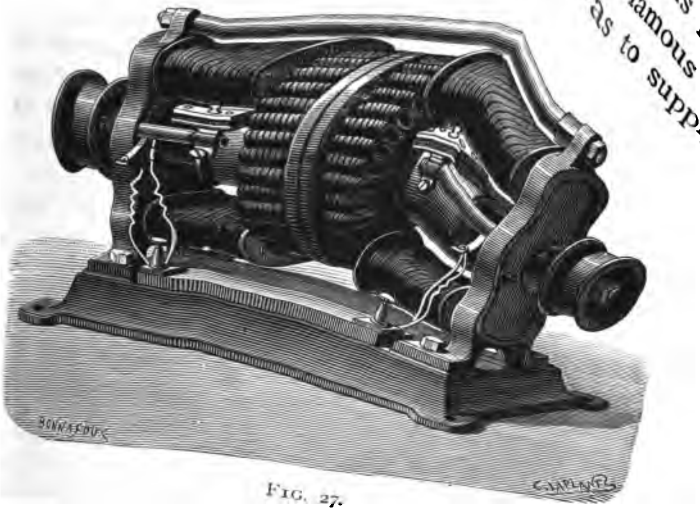


FIG. 27.

of electricity, and everybody was eagerly seeking to learn something of this new wonder. Now, a Report issued by a Committee appointed by the Franklin Institute in America, for a comparative examination of the various machines for light, has quite recently opportunely satisfied the curiosity of the public by giving not only a description of this machine, and of that of Brush, also previously unknown, but also the numerical results of the experiments undertaken by the Committee, and even the verdict of the Committee, who, in spite of the much more favourable results yielded by the Gramme, pronounced in favour of the American machines. We shall, however, have occasion to return to these estim
tions.

Wallace Farmer's machine, which is represented in F
27, is, in fact, nothing more than a reproduction on a la

machine, already spoken of, and of Lontin's is based on the same principle. large iron disc, provided on both sides with electro-magnets, and turning between the t electro-magnets with flat branches, having ge opposite each other. The somewhat les are connected together for tension on each olving disc, and the connecting wires are in with a collector placed on the axle of rota- Gramme system, so as to avoid a reversing commutator. This arrangement, in which there is absolutely no novelty, is shown in Fig. 28.

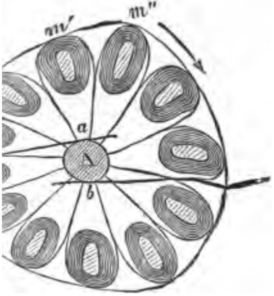


FIG. 28.

It will be perceived that by this arrangement the machine is double, and that each of its parts might act independently; but practically the electrical communi- e so contrived that the currents evolved are united uantity or for tension through the whole circuit. or believes that heating effects are avoided by the ered surface presented by the revolving disc; mmittee pointed out that this advantage is pur- e expense of the great resistance which the air motion of the machine; and further, it may be experiments performed before the Committee ine was heated sufficiently to melt sealing-wax.

achine.—Brush's machine, represented in of those experimented with by the Committee Institute, and it was, in fact, the one to which periority was awarded. In its principle this machine much resembles that of De it is less skilfully put together, and re attempts made by the last-named gentle

This machine consists of a Gramme ring only eight in number, are separated by ra filled up with pieces of iron. This ring between the expanded poles of two oblong magnets, having the poles of the same na each other. In this way the two halves of t

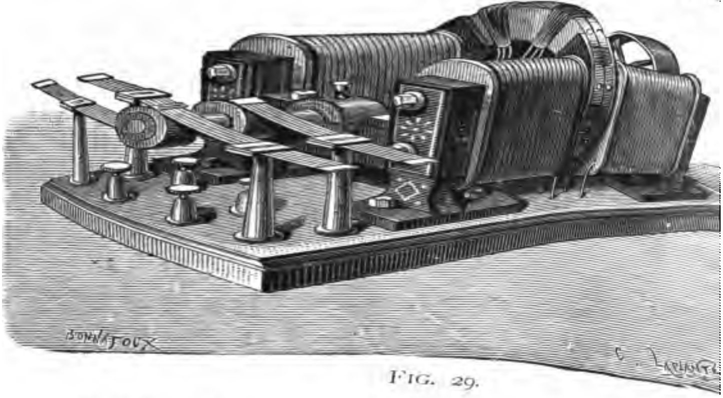


FIG. 29.

surrounded by these poles are polarized uniformly, th south, the other north; and as with this arrangement nately reversed currents are produced, as in De Méri machines, and as such currents are unsuitable for the netization of inducing magnets in dynamo-electric mach it is necessary to put the coils of the revolving ring in c munication with a reversing commutator, for which four bers are required. These rubbers, which are shown in figure to the right and left at the front, are constructed, a the Gramme machines, of bundles of wires arranged lik brush. Fig. 30 indicates the manner in which the wire the coils are connected with each other and with the c opposite coils *b d* are, it will be seen, but these connections are shown in the pair of coils. In order to place the com- position, the ends of the wires are made hollow axle to reach the projecting parts. tor, A B, is put together in such a manner of coils are always in communication with he machine, and the remaining pair has its ted in the place of the neutral line of the

utator itself is made of plates of copper, *a e*, fixed on rings of insulating matter and shaped as in ordinary apparatus of this kind.

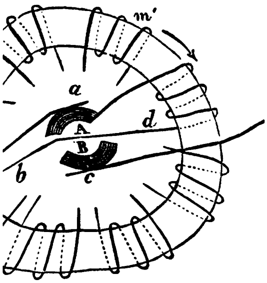


FIG. 30.

The Committee points out that by reason of the iron surfaces which separate the coils being exposed, the ring of this machine is able the more readily to part with its heat, which seldom rises 120° Fahrenheit, in spite of its very great velocity ation. The machine is blamed, however, for its loud noise, which is attributed to the resistance of r, but which is nothing but the sounds due to the alter- ns of magnetization and demagnetization in the portions ring. These effects are produced also in De Méritens' in Lontin's machines, and, what is still more curious, ounds are repeated by the Jablochkoff candles placed e circuit of these machines. This effect is connected the electro-telephonic transmissions, which are explained r work on the telephone.

another form of the machine there are two commu- s corresponding with the two systems formed of the odd and the even coils. "By this means," sa the Committee, "the circuits may be co transmit currents of more or less intensity, to 120 volts, or so as to divide the curre circuits, each supplying an electric light."

We may point out that, under these cir Brush machine is inferior to that of De M cause the iron ring being continuous, the e currents produced by the approach and wit magnetic poles lose their energy, as De Mérit his earliest experiments; 2°, because the inc gain much when the magnetic cores are forme pieces of iron bound together in bundles; 3° presence of a reversing commutator occasions current.

The Brush machine has recently been applie to the illumination of the Park, at the city of America, and if the newspapers of that city ma it has, in conjunction with the electric lamps inventor, an advantage in economy over the sys England and in France in the proportion of 20 machine required only 11 horse-power to supp having the luminous intensity of 200 Carcel lam believe these accounts are much exaggerated, i these 12 lights imply a machine for division, w described by the newspapers we allude to, and w appear to be confounded with that spoken of ab

Bürgin's Machine.—Bürgin, struck like D with the loss of action in the Gramme ring, resu the withdrawal of the iron core from the inducing sought to cause its approach by making it pass coils at longer or shorter intervals. In order to this he formed this ring of six separate rings mount to each other on the same axle, and each having netic core a square frame of iron wires (Fig. 31) o

nd the induced coils. These coils are
pe of a spindle with a curvature so calcu-
angular parts of the cores are nearly on a
ternal spires of these different coils, and
to pass the inducing poles at a very small
frames are also so arranged that the angular
parts of the cores retire from each other so as
selves conformably to a spire of a coil. It fol-
agnetizing actions are produced successively,
irrents due to these actions, as well as to that
between the wires of the coils,
are always of the same intensity in the different phases of
each revolution of the ring.
The induced coils are, moreover, wound in directions alternately reversed, in order to
obtain currents in the same
direction in each half of the
ring. Finally, these coils are
joined to a collector exactly in
the same way as in Gramme's
and in Siemens' machines,
arrangement allows continuous currents to be
l.

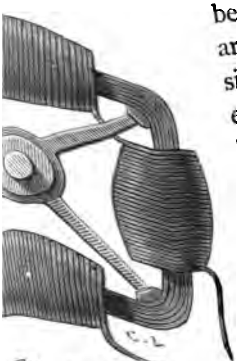


FIG. 31.

nducer has also the same arrangement as that of the
machines, and the induced current traverses it in
ety as in those machines.
riments made in my presence at Geneva, in the work-
f Turetini, who is the maker of these machines,
that they have for a given velocity exactly the same
s power as the ordinary form of Gramme machines,
have the advantage of becoming very much less
In fact, it may be said that they are hardly heated
As regards construction, they also present some
es; thus, for instance, the uncovered parts of the

of these machines, furnishes us with
s :—

small bobbins—one a Gramme, the
n Trouvé's plan. Each has 20 coils.
ontains a greater length of wire by 20
bins are so mounted as to be acted
lectro-magnet, which is wound with a
proportional to the Gramme bobbin.
insulated; there is no loss between the
s to be otherwise with the former, where
in communication with the iron.
e disadvantages I obtain a much better
having projecting pieces.
e coil, with projections, is made of four
nd riveted together so as to form *a single*
ished on the lathe. This core is wound
wire of 0·65 millimetre diameter. *With*
on of 1,500 turns per minute I obtain a
at of 8 to 10 Bunsen cells. There is *no*
n no resistance is interposed in the ex-

hine.—Lontin's machine has a special *in-*
account of the complementary machine by
is divided, and which is the first machine of
nvented. As we shall discuss this kind of
parate chapter, we shall here have but *a few*
out the generator properly so called, which is
Fig. 32. It consists of a core or iron *drum*, on
d a large number of iron cores in four rows
ly. These cores are furnished with magnetizing
ound for tension in such a manner that the end
responds with the beginning of the next. This
by its inventor a magnetic pinion, is mounted
as to turn between the poles of a powerful
with flattened branches, A A, constituting the

inducer, and the coils connected with each oth
coils of the Gramme machine, are joined by deriva
with a collector also like that of the Gramme a
Like most of the preceding, this is a dynamo-electric m

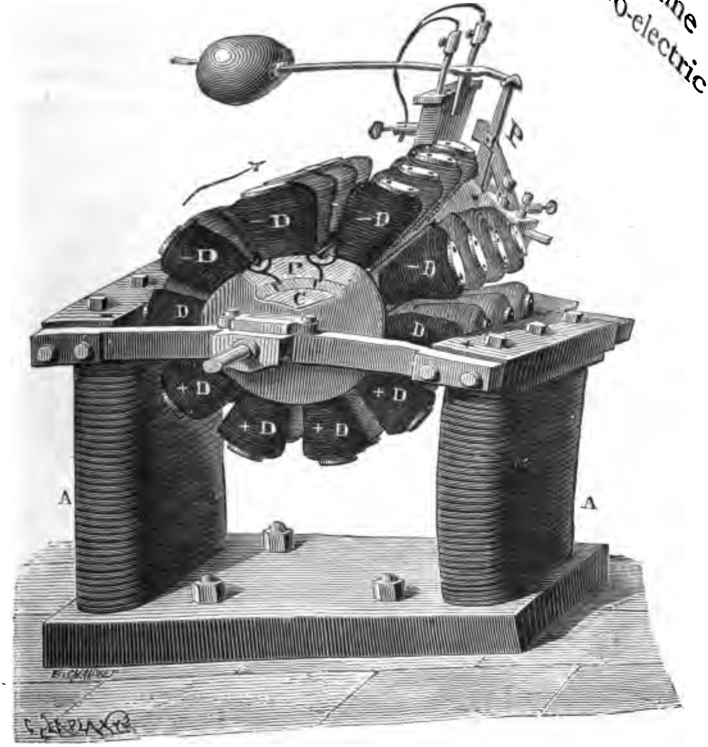


FIG. 32.

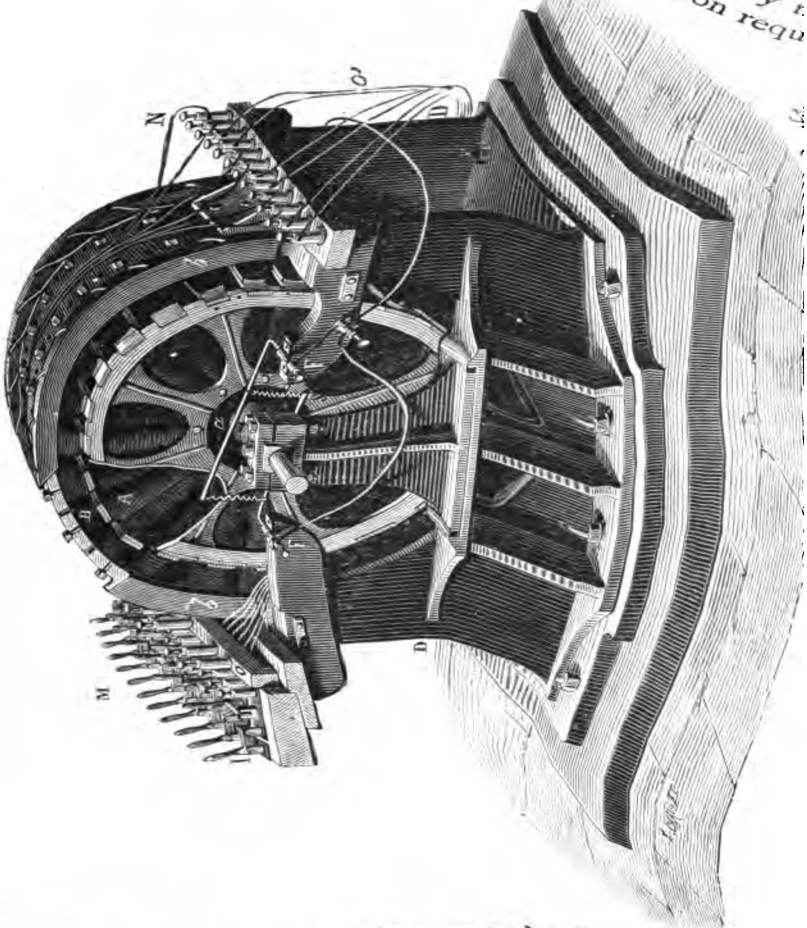
and the inducer is excited by the entire induced current.
the most recently constructed form of the machine, so
improvements, which we must briefly mention, have be
made. In the first place, the polar extremities of the la
inducing electro-magnet have been so arranged that th
tensity of the induced current can be diminished at

to any required degree. For this purpose pieces of iron, movable in a kind of groove, have been adapted to the poles, and can be fixed at a greater or less distance from the wires of the magnetic pinion. Secondly, the collector is placed apart from the axis of rotation, so that the machine may be covered up and protected, and in order to accomplish this it was necessary to make the communications through the axis of rotation, and the contacts of the collector have been so arranged as to enclose it on the two sides of the axle under a pressure produced by a counterpoise P. The rubbing parts themselves are made of an alloy of lead and zinc, and fitted to elastic metallic supports.

MACHINES WITH ALTERNATE REVERSIONS OF THE CURRENTS, ESPECIALLY APPLICABLE TO THE DIVISION OF THE ELECTRIC LIGHT.

For a long time it was a matter for complaint that the generators of the electric light could supply only a very limited number of lights, and the *desideratum* generally required was the construction of a generator capable of furnishing electricity to several derived circuits in quantity sufficient to maintain lights in different places. Although several combinations for solving this problem were long ago proposed, it is only recently that the solution has been accomplished in a satisfactory manner, both as regards the generator and as regards the lights themselves, and we are indebted to Lontin for this important novelty.

Lontin's System.—Lontin's machine for the production of light succeeded not only in dividing the electric light, but also in so dividing it that the total intensity m tributed among the several lights as occasion requ



In principle this machine consists of a series of electro-magnets, fixed in the interior of an iron crown placed very, having in its centre a rotating electro-magnetic system posed of as many magnetic cores as there are electro- gnets on the crown. Fig. 33 shows this machine, in which e rotating interior electro-magnets represent the inducing, and the fixed electro-magnets the induced system.

The inducing system, which is merely the *magnetic pinion* of Lontin's generators already described on page 98, is composed of an iron cylinder to which are riveted a series of iron plates somewhat resembling the teeth of a pinion, and on these the magnetizing coils A A are wound for tension. In order that the spires of the coils may not shift under the influence of the centrifugal force, and of the elongation caused by the rather large amount of heat developed, the plates of iron forming the cores are thicker at their free extremities than at their points of connection with the iron cylinder, and this greater thickness plays the part of retaining discs for the spires, which are further maintained in their position by abutting against horizontal iron pieces mounted on two bronze wheels. Finally, the coils are so wound that the polarity of the cores are reversed from one plate to the other, so that the motion of the drum brings magnets of alternately opposite poles before the iron cores of the induced system, which thus receive alternately reversed polarizations.

This inducing system is of course magnetized continuously by the dynamo-electric generator, which we have already described, and which may be mounted on the same axle. Another machine may, however, be substituted for this generator; or even a voltaic battery may be used, but in that case the conditions will be very disadvantageous as regards economy.

The induced system is composed, as we have seen, of a large stationary iron ring, fitted inside with a series of iron plates fixed transversely, like the teeth of a wheel projecting internally, and surrounded with magnetizing coils, B B B. These coils are connected to each other in couples, so as to form a complete electro-magnetic syst nd their free ex-

tremities end severally in the commuta
all the currents they supply to be drawn
lectively by means of the rubbers a s.
revolves the inducer, which is so arrange
cores of the two systems pass each othe
Thus each of the induced systems is mag
directions alternately; for if one of the co
system, acting on one of the cores of the
polarized north, the adjoining core of the
will be subjected to the action of a south
rent will always be produced in the induced sys
with the commutator. When the inducer has
polarities will have different signs, and a cu
reverse direction will be obtained.

As the action we have examined will be simu
repeated in all the electro-magnetic systems of th
bobbins, each of these is able to supply its own acti
independent of the rest, an arrangement which allo
division of the electric effect. Supposing that eac
induced magnetic systems formed of two bobbins is
of supplying a current powerful enough to maintain an
light, the machine represented in Fig. 33 would give 1
and if these were desired of different intensities, it wo
necessary merely to take away currents from some
lights and put them in communication with those lam
are to be brightest. As the induced system is fixed, n
is easier than to combine the lights in any required m
and as there are neither rubbers nor revolving conta
loss of electricity can occur.

The commutator M is so arranged as to act on as
contact plates as the machine supplies currents ava
for the production of light. The number of these cu
depends on the construction of the machine, and we
seen that the one represented in Fig. 33 furnishes t
currents. There are therefore twelve contact plates, a
each of these correspond two binding screws, one of

connected with the contact itself, while the other communicates with a hand circuit-breaker, I. The former receives e wire of the corresponding magnetic system, the latter he wire which leads to the electric lamp. Moreover, the arious contacts are themselves provided with handles, which connect them two by two and enable an instantaneous union or separation of the partial currents to be made.

This machine has for some time been applied to the lighting of the terminus of the Lyons railways, where it supplies 31 electric lights. These lights are produced by a single electric generator and from two induced systems of 25 coils each. By joining these coils together, and interposing in each of their circuits several electric light regulators on the Lontin system, it has been found possible, by a combination of the coils suitable to the length of the circuit, to carry to 31, as I have said, the number of illuminated points, each equal to nearly 40 Carcel lamps.

For six months these machines have been established at the terminus of the *Chemins de Fer de l'Ouest* (*Saint-Lazare* station), where they supply 12 lights, two of which, placed at the entrance to the station, are 700 metres from the machine, a fact that triumphantly replies to the objection made by some persons to the use of alternately reversed currents, which, according to them, would be incapable of producing light at a greater distance than 200 metres.

Gramme's System.—This system is merely a modification of the foregoing, only the induced apparatus is formed of a rather long iron cylinder fixed horizontally, as shown in Fig. 34, and otherwise arranged like the ring in the same inventor's machines. All the small coils, however, A A, which surround this cylinder, instead of being attached to a collector, are distributed in four separate series, each connected with a particular circuit, so that they successively supply the current to four different circuits. The inducing system is a kind of magnetic pinion formed of eight straight electro-

magnets, B B, which move inside of the cylind foregoing apparatus, and which, being of contrar successively supply in each section of the induc rents alternately reversed. This inducing system by a Gramme generator like that described on pag

It is this system of machines which supplies the

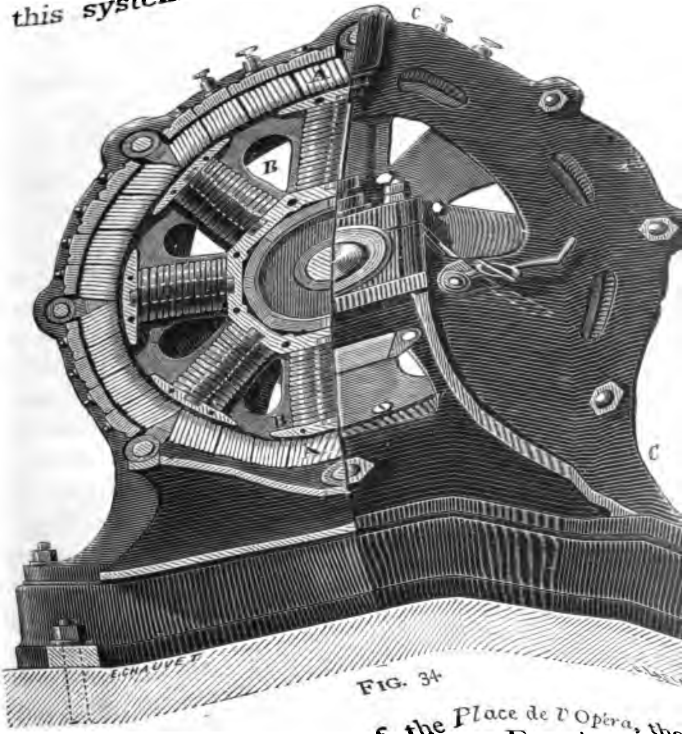


FIG. 34

required for the lighting of the *Place de l'Opéra*, the *de l'Opéra*, and the *Place du Théâtre-Français*. Four are employed for this purpose; one is placed in of the opera-house, two others in cellars near the the *Avenue de l'Opéra*, and the fourth is set up houses adjoining the *Place du Théâtre-Franço*

Each of the currents produced by this kind of machine is able to light four Jablochkoff candles, and consequently each system of machines maintains 16 electric candles. There are, it is true, two candles lighted at once in each lamp in the *Place de l'Opéra*, but there is only one in the lamps of the *Avenue de l'Opéra* and in those of the *Place du Théâtre Français*.

Experiment has shown that about 1 horse-power of motive force must be reckoned for the maintenance of each of these candles, which, however, last little more than one hour and a half. But to this subject we shall presently return.

In Fig. 34 the machine is shown with one half in section, the other half in elevation. It will be seen that the electro-magnetic system is covered up by a cast-iron frame at the two ends, and by a casing of wood on the curved part.

Gramme has recently constructed a new form of these machines, in which the thickness of the wire in the induced coils, their grouping, and their connection with each other, have been so adjusted as to supply the maximum effect with the Jablochkoff candles, while using the least possible motive force. With a horse-power of 4 a machine of small size was capable of lighting eight candles.

This machine is moreover able to supply at pleasure 8, 6, or 4 lights. In the former case it absorbs a horse-power of 4½; in the second, 2·8 horse-power; in the third, 2·1 horse-power. These lights are equal to 25 gas-jets, and the Jablochkoff candles which supply them have carbons 3 millimetres in diameter. Rapieff's machine, mentioned on page 81, is a machine of this kind.

At the establishment of the *Société général d' électricité* there is also a form of Gramme machine, giving lights equal to from 70 to 84 gas-jets, with carbons 6 to 8 millimetres in diameter. Thanks to these different forms of the machine, lights may now be obtained giving illuminations equal, according to the requirements, to 25, 52, 70, and 84 unshaded gas-jets, and these illuminations are diminished by only

10 per cent. when, instead of enamelled globes, globes of wickered or waved glass are used.

Siemens' System.—Siemens' machines for dividing the light with reversions of currents, which are represented in

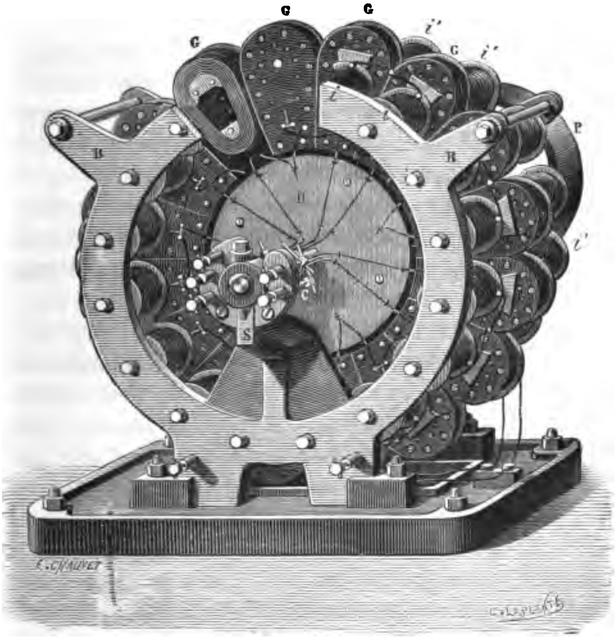


FIG. 35.

Fig. 35, have been constructed for 4, for 8, and for 16 lights. They are, however, also based on the principle of Lontin's system, but under different conditions, and taking advantage of the dynamo-electric effects of the same maker. They require, it is said, a motive force not exceeding 13 horse-power. If we take, for instance, the form of the machine adapted for 16 candles, we observe that the inducing system, Gramme, is formed of the two vertical crowns of electro-magnets, *i i*, *i i*, fixed parallel to and in front of each other, and turning between them is the induced system constructed of as many galvanometric frames, G G, as there are electro-magnets in each of the two crowns. They are, of course, insulated from the cast-iron frame B B, on which they are mounted by means of ebonite plates, and they are so wound that a north pole is always between two south poles, and *vice versâ.* It will readily be understood that the electro-magnets placed opposite to each other on the two supports are of opposite polarities, and that consequently a galvanometric frame, when it comes between two consecutive cores of this double inducing system, will be affected in four different directions—first on the two faces of the multiplier, and secondly on the two parts opposite to the galvanometric frame.

The induced system is formed of a bronze wheel, on the circumference of which are fixed the 16 galvanometric multipliers, G G, already mentioned; these multipliers are wound on two wooden supports fixed between two plates of copper pierced with holes and having the shape of enlongated sectors. Each multiplier is composed of 23 rows of spires, to the number of 17 in each row, and the wire has a diameter of 18 tenths of a millimetre. They have, however, no iron cores, and present exactly the appearance of a galvanometric frame. They are fixed by their sides on the copper wheel, and are fitted with such exactness that one would suppose that the wheel was provided with two large metallic circumferences externally presenting circular notches corresponding with each multiplier. The holes in the metallic sides are for the purpose of admitting air to cool the enclosed multipliers, a precaution neglected in France, but always taken in the machines constructed abroad.

The central part of the wheel of the induced system is occupied by a thick circular plate D, whereon are fixed the wires by which the coils are connected with the collector C and with each other. The combination of these wires, however, is very simple; the multipliers are divided, as in the Gramme machine, into four series, and those of each series are joined together for tension. One of the similar ends of each series leads to a metallic ring fixed on the axle of rotation of the wheel, and the other ends lead to four other rings insulated from each other, and pressed by the rubbers C in communication with the terminal binding screws of the four circuits corresponding with the electric lamps. These circuits are completed by a connection with a rubber which presses on the ring, and is common to all the multipliers. The current of the exciting machine, which is placed beside the other, corresponds, however, with 32 electro-magnets of the two crowns of the inducing system, which electro-magnets are joined for tension, each being composed of five layers of 32 spires, in wire of 2 millimetres diameter. P is the pulley for the prime mover.

A remarkable feature of this machine is the small amount of heating it develops. The inducing electro-magnets are seldom higher than 30° C; the multipliers are indeed a little more heated, but I am unable to state their temperature.

According to Boistel, the motive power required to drive this machine for 16 lights will be 13 horse-power (German standard).* The velocity of rotation of the division machine will be 500 turns per minute, and that of the exciting machine 1,375 turns. In the form of the machine intended for 8 lights, the force employed is 7 horse-power, and the speed of the division machine 550 turns; that of the exciting machine 1,375 turns. In the form for 4 lights, the force used is 4 horse-power, the division machine making 600 and the exciting machine 1,100 turns per minute.

Boistel thinks that, by some slight modification, the 4-light machine might be arranged for 6 and the 8-light machine for 12 lights.

* It seems that the "horse-power" used as the unit in Germany is of 80

The principle of Siemens' machines is based only on the inductive reactions produced by the passage of the spires of the multipliers before an electro-magnetic inducer, and under the influence of a tangential motion. This is not precisely the effect produced in Faraday's classic experiment, and the direction of the currents produced is even different from what it should be, according to the generally received notions of induction. I have studied in detail these different kinds of inductions in a paper presented to the *Académie* on the 24th February, and the substance of this paper will be found in Note A at the end of this volume.

We have lately visited with much interest a large establishment which Siemens Brothers have organized in Paris, at No. 8 *Rue Picot*, for the construction of those machines under the management of Boistel.

Jablochkoff's System. — Jablochkoff has also constructed an induction machine with reversed currents, and with means for dividing the light, which is intended to admit of being more easily cleaned than the Gramme machine, and to work with less motive power without becoming heated. For this purpose Jablochkoff uses for inducers a cast-iron toothed wheel, having the teeth slightly inclined to the direction of the axis, and separated from each by a rather wide space. A coil of wire winds between these teeth in the manner shown in Fig. 36, and when this is traversed by a current the teeth assume alternately opposite polarities, which convert

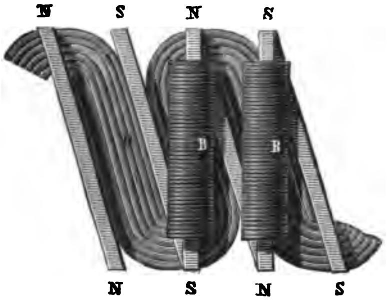


FIG. 36.

the system into a kind of electro-magnet with numerous poles, acting like Lontin's magnetic pinion. The induced system is formed of a series of straight electro-magnets B B, with expanded poles, and placed parallel to the axis of the wheel crossing its teeth S S, N N, S S, so that when at one end they are in contact with one tooth, at the other end they touch the next tooth. As these teeth are polarized alternately in opposite ways, it follows that for a certain position of the wheel the electro-magnets will be polarized north-south, and this will give rise to magneto-electric currents in the coils which surround them; but when after leaving this position the different parts of the polarized teeth are brought before the different parts of the induced coils, there will be produced these reversed polar currents and dynamic currents which will carry on the magneto-electric action and augment it, as in the machines of De Méritens. Thus, by very simple constructive arrangements, a relatively powerful induction machine is obtained. In the form of the machine working in Jablochkoff's establishment, there are 36 induction coils, and these are so joined as to give three series for tension, each formed of 12 coils joined for quantity. There are, of course, 36 teeth to the wheel, and under these conditions two Jablochkoff candles are kept lighted, with a motive power equivalent to that of two men, but under the influence of an induction current coming from a small Gramme machine. In this way the current from the Gramme machine is transformed under favourable conditions into alternately reversed currents.

COMPARATIVE EXPERIMENTS ON THE EFFECTS PRODUCED BY THE DIFFERENT ELECTRO-MAGNETIC MACHINES.

The study of the comparative effects produced by the of great importance, and this has been so well understood that at various times there have been instituted experiments upon it more or less conclusive. As early as 1855 Ed. Becquerel had made an important investigation on batteries as regards this point, and the work was continued by Tresca at the *Conservatoire des Arts et Métiers* with the magneto-electric machines of the *Alliance* Company. At a later period these machines were the subject of laborious investigations, conducted by Reynaud and Degrand at the Directory of Lighthouses. A more profound study of the question was undertaken by Le Roux in 1865, and this was the subject of a very interesting communication printed in the *Bulletin de la Société d'Éncouragement* (*tome XIV.*, page 699). Jamin, in conjunction with Rogers, examined from a scientific point of view the *work* produced by the same machines, and in 1877 Tresca, in a paper read before the *Académie des Sciences*, gave a complete investigation of the effects produced by the Gramme machine. At length the success of these machines, and of their application to lighthouses, so much attracted the attention of the English that in 1877 they considered it necessary to appoint a Commission of Inquiry to examine this question. This Commission was composed of Tyndall, Douglass, Sabine, Edwards, Drew-Atkings, and Minster, with Douglass as reporter; and it shortly afterwards published a Report, known as *The Report of the Trinity House on the South Foreland Lighthouse*, and this was for some time regarded as the best authority on the subject. The Americans, however, were also desirous of examining the question, and the Franklin Institute, after an invitation to the makers of machines to compete, which was responded to by only three, appointed a Commission composed of Briggs, Rogers, Chase, Houston, Thomson, Rand, Jones, Sartain, and Knight, and this Commission, subdivided into three committees, presented a double report, which was published in the Bulletin of the Franklin Institute. We shall give the numerical results from this report after those of the English Commission

Notwithstanding the importance of these documents, we believe the question is far from having been settled, for we find that in them the spirit of nationality has played so large a part that they cannot be implicitly trusted. Nor can we rely on the figures given by the several makers and inventors of the machines. Not only are the majority of these individuals without the scientific acquirements necessary for exact results, but there are personal interests the influence of which it is impossible to eliminate from the statements put forth, and for my part I believe that we must deduct a great deal from the results which have been announced. Amidst this confusion it is difficult to see where we are, and it is much to be desired that an international commission should undertake to completely clear up the question. In the meanwhile we give the results obtained by the English and American Commissions in the two tables on pages 123, 124, and 125, and to these we shall add a third table, drawn up by Shoolbred, from the most recent experiments.

In order to define the values of the figures in these tables, we must mention that the standard for light adopted in them, and denominated a *candle*, represents the light of a spermaceti candle, having an intensity equal to eight-tenths of the light of a *bougie de l'Étoile.* A Carcel lamp represents about 9½ candles (9·6).

In the table of English measurements mention is made of the *condensed radiating power* and of the *diffused radiating power*. It is important that these expressions should be understood. The condensed radiating power, as we have already indicated on p. 21, is applied to the light given off by a continuous current between two carbons, one of which is hollowed out in a cup shape and so turned as to act as a reflector, and to emit the light externally with increase of the illuminating power. The diffused radiating power is that which is produced by a light between two carbons without a cup-shaped hollow.

In the American table mention is made of *foot-pounds:*

is connected with the contact itself, while the other communicates with a hand circuit-breaker, I. The former receives the wire of the corresponding magnetic system, the latter the wire which leads to the electric lamp. Moreover, the various contacts are themselves provided with handles, which connect them two by two and enable an instantaneous union or separation of the partial currents to be made.

This machine has for some time been applied to the lighting of the terminus of the Lyons railways, where it supplies 31 electric lights. These lights are produced by a single electric generator and from two induced systems of 25 coils each. By joining these coils together, and interposing in each of their circuits several electric light regulators on the Lontin system, it has been found possible, by a combination of the coils suitable to the length of the circuit, to carry to 31, as I have said, the number of illuminated points, each equal to nearly 40 Carcel lamps.

For six months these machines have been established at the terminus of the *Chemins de Fer de l'Ouest* (*Saint-Lazare* station), where they supply 12 lights, two of which, placed at the entrance to the station, are 700 metres from the machine, a fact that triumphantly replies to the objection made by some persons to the use of alternately reversed currents, which, according to them, would be incapable of producing light at a greater distance than 200 metres.

Gramme's System.—This system is merely a modification of the foregoing, only the induced apparatus is formed of a rather long iron cylinder fixed horizontally, as shown in Fig. 34, and otherwise arranged like the ring in the same inventor's machines. All the small coils, however, A A, which surround this cylinder, instead of being attached to a collector, are distributed in four separate series, each connected with a particular circuit, so that they successively supply the current to four different circuits. The inducing system is a kind of magnetic pinion formed of eight straight electro-

inside of the cylinder, as in the
/hich, being of contrary polarities,
h section of the induced coil cur-
This inducing system is excited
ce that described on page 74.
:hines which supplies the currents

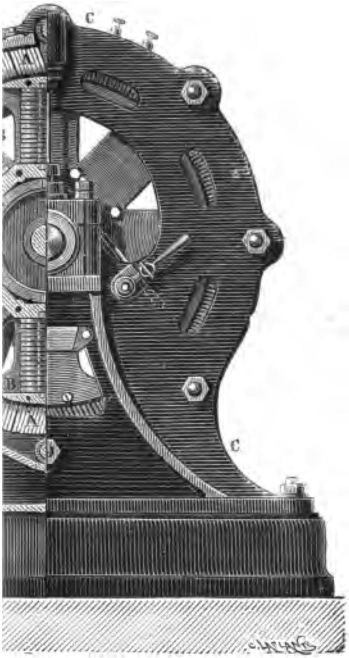


FIG. 34.

f the *Place de l'Opéra*, the *Avenue*
Théâtre-Français. Four machines
pose; one is placed in the cellars
:hers in cellars near the middle of
l the fourth is set up in one of the
du Théâtre-Français.

of which are wound the induced coils. These coils are wound to the shape of a spindle with a curvature so calculated that the four angular parts of the cores are nearly on a level with the external spires of these different coils, and therefore are able to pass the inducing poles at a very small distance. The frames are also so arranged that the angular and uncovered parts of the cores retire from each other so as to present themselves conformably to a spire of a coil. It follows that the magnetizing actions are produced successively, and that the currents due to these actions, as well as to that between the wires of the coils, are always of the same intensity in the different phases of each revolution of the ring. The induced coils are, moreover, wound in directions alternately reversed, in order to obtain currents in the same direction in each half of the ring. Finally, these coils are joined to a collector exactly in the same way as in Gramme's and in Siemens' machines, and this arrangement allows continuous currents to be obtained.

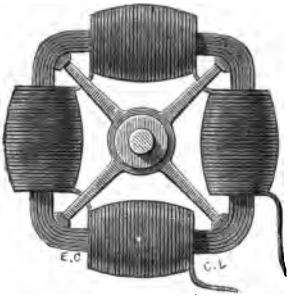


FIG. 31.

The inducer has also the same arrangement as that of the Siemens machines, and the induced current traverses it in its entirety as in those machines.

Experiments made in my presence at Geneva, in the workshops of Turetini, who is the maker of these machines, showed that they have for a given velocity exactly the same luminous power as the ordinary form of Gramme machines, but they have the advantage of becoming very much less heated. In fact, it may be said that they are hardly heated at all. As regards construction, they also present some advantages; thus, for instance, the uncovered parts of the

he rings on the axis
operation with the
teresting and a very

also constructed
rly the same prin-
th a reaction of the
h is effected at the
a method similar to
early as 1855 in his
evolving armatures.
is formed of a large
tally on its axis, and
s, as in the circular
discs turn the iron
of electro-magnets,
placed successively
he inducing electro-
tion currents, which,
cing coil and supply
rent. This arrange-
armangeat's electro-

is now being made
arranged as we have
two straight electro-
and their iron discs
hich move two rings
, having a common
o give currents recti-
der these conditions
sed electro-magnetic
nagnetic pieces are
maximum of their

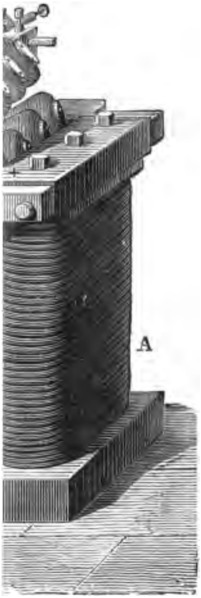
J. Bellot, the maker of these machines, furnishes us with the following particulars:—

"I have made two small bobbins—one a Gramme, the other with projections on Trouvé's plan. Each has 20 coils. The Gramme bobbin contains a greater length of wire by 20 per cent. These bobbins are so mounted as to be acted upon by the same electro-magnet, which is wound with a thick wire of a length proportional to the Gramme bobbin. This last is perfectly insulated; there is no loss between the coils; but it happens to be otherwise with the former, where some of the coils are in communication with the iron.

"In spite of these disadvantages I obtain a much better result with the coil having projecting pieces.

"The core of the coil, with projections, is made of four sheets of iron, cut and riveted together so as to form a single mass, which was finished on the lathe. This core is wound with 75 metres of wire of 0·65 millimetre diameter. With a velocity of rotation of 1,500 turns per minute I obtain a current equal to that of 8 to 10 Bunsen cells. There is no heating, even when no resistance is interposed in the external circuit."

Lontin's Machine.—Lontin's machine has a special interest for us on account of the complementary machine by which the effect is divided, and which is the first machine of the kind ever invented. As we shall discuss this kind of machine in a separate chapter, we shall here have but a few words to say about the generator properly so called, which is represented in Fig. 32. It consists of a core or iron drum, on which are fixed a large number of iron cores in four rows placed obliquely. These cores are furnished with magnetizing coils, D D D, wound for tension in such a manner that the end of one coil corresponds with the beginning of the next. This system, called by its inventor a magnetic pinion, is mounted on an axle so as to turn between the poles of a powerful electro-magnet with flattened branches, A A, constituting the each other, like the d by derivation wires Gramme apparatus. mo-electric machine,



nduced current. In the machine, some mention, have been remities of the large rranged that the in- diminished at will to any required degree. For this purpose pieces of iron, movable in a kind of groove, have been adapted to the poles, and can be fixed at a greater or less distance from the wires of the magnetic pinion. Secondly, the collector is placed apart from the axis of rotation, so that the machine may be covered up and protected, and in order to accomplish this it was necessary to make the communications through the axis of rotation, and the contacts of the collector have been so arranged as to enclose it on the two sides of the axle under a pressure produced by a counterpoise P. The rubbing parts themselves are made of an alloy of lead and zinc, and fitted to elastic metallic supports.

MACHINES WITH ALTERNATE REVERSIONS OF THE CURRENTS, ESPECIALLY APPLICABLE TO THE DIVISION OF THE ELECTRIC LIGHT.

For a long time it was a matter for complaint that the generators of the electric light could supply only a very limited number of lights, and the *desideratum* generally required was the construction of a generator capable of furnishing electricity to several derived circuits in quantity sufficient to maintain lights in different places. Although several combinations for solving this problem were long ago proposed, it is only recently that the solution has been accomplished in a satisfactory manner, both as regards the generator and as regards the lights themselves, and we are indebted to Lontin for this important novelty.

Lontin's System.—Lontin's machine for the production of light succeeded not only in dividing the electric light, but also in so dividing it that the total intensity may be distributed among the several lights as occasion requires.

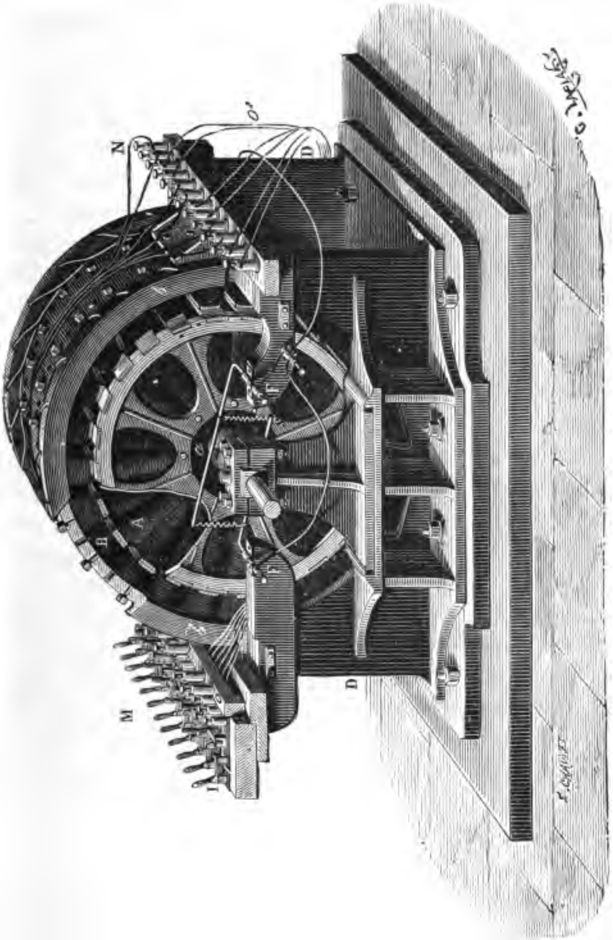


FIG. 33.

In principle this machine consists of a series of electromagnets, fixed in the interior of an iron crown placed vertically, having in its centre a rotating electro-magnetic system composed of as many magnetic cores as there are electro-magnets on the crown. Fig. 33 shows this machine, in which the rotating interior electro-magnets represent the inducing, and the fixed electro-magnets the induced system.

The inducing system, which is merely the *magnetic pinion* of Lontin's generators already described on page 98, is composed of an iron cylinder to which are riveted a series of iron plates somewhat resembling the teeth of a pinion, and on these the magnetizing coils A A are wound for tension. In order that the spires of the coils may not shift under the influence of the centrifugal force, and of the elongation caused by the rather large amount of heat developed, the plates of iron forming the cores are thicker at their free extremities than at their points of connection with the iron cylinder, and this greater thickness plays the part of retaining discs for the spires, which are further maintained in their position by abutting against horizontal iron pieces mounted on two bronze wheels. Finally, the coils are so wound that the polarity of the cores are reversed from one plate to the other, so that the motion of the drum brings magnets of alternately opposite poles before the iron cores of the induced system, which thus receive alternately reversed polarizations.

This inducing system is of course magnetized continuously by the dynamo-electric generator, which we have already described, and which may be mounted on the same axle. Another machine may, however, be substituted for this generator; or even a voltaic battery may be used, but in that case the conditions will be very disadvantageous as regards economy.

The induced system is composed, as we have seen, of a large stationary iron ring, fitted inside with a series of iron plates fixed transversely, like the teeth of a wheel projecting internally, and surrounded with magnetizing coils, B B B. These coils are connected to each other in couples, so as to form a complete electro-magnetic system, and their free extremities end severally in the commutator M, which enables all the currents they supply to be drawn off separately or collectively by means of the rubbers *a s*. Inside of this ring revolves the inducer, which is so arranged that the magnetic cores of the two systems pass each other without touching. Thus each of the induced systems is magnetized in opposite directions alternately; for if one of the cores of the inducing system, acting on one of the cores of the induced system, is polarized north, the adjoining core of the induced system will be subjected to the action of a south polarity, and a current will always be produced in the induced system connected with the commutator. When the inducer has advanced, the polarities will have different signs, and a current in the reverse direction will be obtained.

As the action we have examined will be simultaneously repeated in all the electro-magnetic systems of the induced bobbins, each of these is able to supply its own action and is independent of the rest, an arrangement which allows of the division of the electric effect. Supposing that each of the induced magnetic systems formed of two bobbins is capable of supplying a current powerful enough to maintain an electric light, the machine represented in Fig. 33 would give 12 lights, and if these were desired of different intensities, it would be necessary merely to take away currents from some of the lights and put them in communication with those lamps that are to be brightest. As the induced system is fixed, nothing is easier than to combine the lights in any required manner, and as there are neither rubbers nor revolving contacts no loss of electricity can occur.

The commutator M is so arranged as to act on as many contact plates as the machine supplies currents available for the production of light. The number of these currents depends on the construction of the machine, and we have seen that the one represented in Fig. 33 furnishes twelve currents. There are therefore twelve contact plates, and to each of these correspond two binding screws, one of which is connected with the contact itself, while the other communicates with a hand circuit-breaker, I. The former receives the wire of the corresponding magnetic system, the latter the wire which leads to the electric lamp. Moreover, the various contacts are themselves provided with handles, which connect them two by two and enable an instantaneous union or separation of the partial currents to be made.

This machine has for some time been applied to the lighting of the terminus of the Lyons railways, where it supplies 31 electric lights. These lights are produced by a single electric generator and from two induced systems of 25 coils each. By joining these coils together, and interposing in each of their circuits several electric light regulators on the Lontin system, it has been found possible, by a combination of the coils suitable to the length of the circuit, to carry to 31, as I have said, the number of illuminated points, each equal to nearly 40 Carcel lamps.

For six months these machines have been established at the terminus of the *Chemins de Fer de l'Ouest* (*Saint-Lazare* station), where they supply 12 lights, two of which, placed at the entrance to the station, are 700 metres from the machine, a fact that triumphantly replies to the objection made by some persons to the use of alternately reversed currents, which, according to them, would be incapable of producing light at a greater distance than 200 metres.

Gramme's System.—This system is merely a modification of the foregoing, only the induced apparatus is formed of a rather long iron cylinder fixed horizontally, as shown in Fig. 34, and otherwise arranged like the ring in the same inventor's machines. All the small coils, however, A A, which surround this cylinder, instead of being attached to a collector, are distributed in four separate series, each connected with a particular circuit, so that they successively supply the current to four different circuits. The inducing system is a kind of magnetic pinion formed of eight straight electro-

magnets, B B, which move inside of the cylinde
foregoing apparatus, and which, being of contrar
successively supply in each section of the induce
rents alternately reversed. This inducing system
by a Gramme generator like that described on pag
It is this system of machines which supplies th

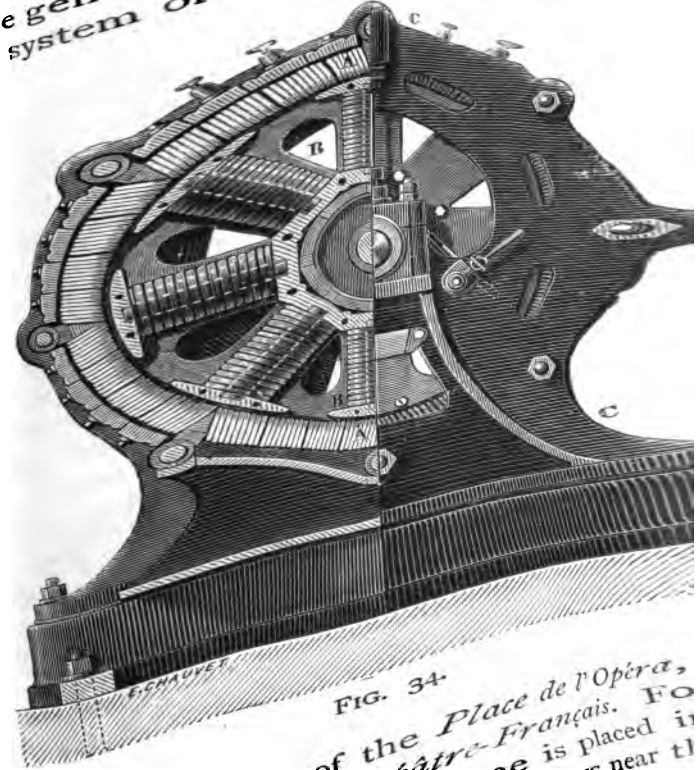


FIG. 34.

required for the lighting of the *Place de l'Opéra*,
de l'Opéra, and the *Place du Théâtre-Français*. Fo
are employed for this purpose; one is placed i
of the opera-house, two others in cellars near t
the *Avenue de l'Opéra*, and the fourth is set up
houses adjoining the *Place du Théâtre-Français*

Each of the currents produced by this kind of machine is able to light four Jablochkoff candles, and consequently each system of machines maintains 16 electric candles. There are, it is true, two candles lighted at once in each lamp in the *Place de l'Opéra*, but there is only one in the lamps of the *Avenue de l'Opéra* and in those of the *Place du Théâtre-Français*.

Experiment has shown that about 1 horse-power of motive force must be reckoned for the maintenance of each of these candles, which, however, last little more than one hour and a half. But to this subject we shall presently return.

In Fig. 34 the machine is shown with one half in section, the other half in elevation. It will be seen that the electro-magnetic system is covered up by a cast-iron frame at the two ends, and by a casing of wood on the curved part.

Gramme has recently constructed a new form of these machines, in which the thickness of the wire in the induced coils, their grouping, and their connection with each other, have been so adjusted as to supply the maximum effect with the Jablochkoff candles, while using the least possible motive force. With a horse-power of 4 a machine of small size was capable of lighting eight candles.

This machine is moreover able to supply at pleasure 8, 6, or 4 lights. In the former case it absorbs a horse-power of 4½; in the second, 2·8 horse-power; in the third, 2·1 horse-power. These lights are equal to 25 gas-jets, and the Jablochkoff candles which supply them have carbons 3 millimetres in diameter. Rapieff's machine, mentioned on page 81, is a machine of this kind.

At the establishment of the *Société général d' électricité* there is also a form of Gramme machine, giving lights equal to from 70 to 84 gas-jets, with carbons 6 to 8 millimetres in diameter. Thanks to these different forms of the machine, lights may now be obtained giving illuminations equal, according to the requirements, to 25, 52, 70, and 84 unshaded gas-jets, and these illuminations are diminished by only

10 per cent. when, instead of ename
wickered or waved glass are used.

Siemens' System.—Siemens' machi
light with reversions of currents, which

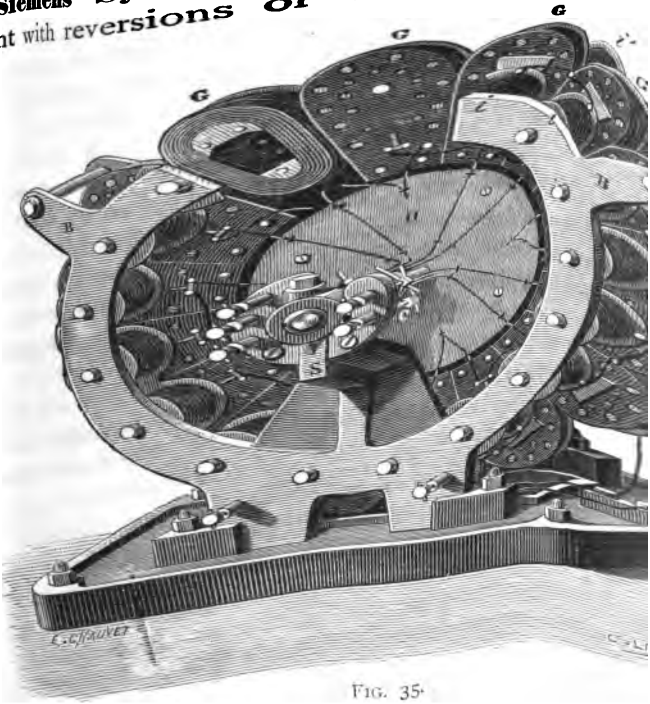


FIG. 35.

Fig. 35, have been constructed for 4, for 8, and for
They are, however, also based on the principle o
system, but under different conditions, and taking a
of the dynamo-electric effects of the same make
require, it is said, a motive force not exceeding
power. If we take, for instance, the form of the
adapted for 16 candles, we observe that the inducin
instead of being mobile, as in the systems of Lont

Gramme, is formed of the two vertical crowns of electro-magnets, *i i*, *v' i'*, fixed parallel to and in front of each other, and turning between them is the induced system constructed of as many galvanometric frames, G G, as there are electro-magnets in each of the two crowns. They are, of course, insulated from the cast-iron frame B B, on which they are mounted by means of ebonite plates, and they are so wound that a north pole is always between two south poles, and *vice versâ*. It will readily be understood that the electro-magnets placed opposite to each other on the two supports are of opposite polarities, and that consequently a galvanometric frame, when it comes between two consecutive cores of this double inducing system, will be affected in four different directions—first on the two faces of the multiplier, and secondly on the two parts opposite to the galvanometric frame.

The induced system is formed of a bronze wheel, on the circumference of which are fixed the 16 galvanometric multipliers, G G, already mentioned; these multipliers are wound on two wooden supports fixed between two plates of copper pierced with holes and having the shape of enlongated sectors. Each multiplier is composed of 23 rows of spires, to the number of 17 in each row, and the wire has a diameter of 18 tenths of a millimetre. They have, however, no iron cores, and present exactly the appearance of a galvanometric frame. They are fixed by their sides on the copper wheel, and are fitted with such exactness that one would suppose that the wheel was provided with two large metallic circumferences externally presenting circular notches corresponding with each multiplier. The holes in the metallic sides are for the purpose of admitting air to cool the enclosed multipliers, a precaution neglected in France, but always taken in the machines constructed abroad.

The central part of the wheel of the induced system is occupied by a thick circular plate D, whereon are fixed the wires by which the coils are connected and with each other. The combination ever, is very simple; the multipliers are Gramme machine, into four series, and are joined together for tension. One of each series leads to a metallic ring fixed tion of the wheel, and the other ends rings insulated from each other, and press c in communication with the terminal the four circuits corresponding with the elec circuits are completed by a connection presses on the ring, and is common to The current of the exciting machine, whic the other, corresponds, however, with 32 the two crowns of the inducing system, nets are joined for tension, each being comp of 32 spires, in wire of 2 millimetres diamete for the prime mover.

A remarkable feature of this machine is of heating it develops. The inducing ele seldom higher than 30° C; the multipliers a more heated, but I am unable to state their

According to Boistel, the motive power re this machine for 16 lights will be 13 horse- standard).* The velocity of rotation of th chine will be 500 turns per minute, and that machine 1,375 turns. In the form of the mac for 8 lights, the force employed is 7 horse-p speed of the division machine 550 turns; that machine 1,375 turns. In the form for 4 li used is 4 horse-power, the division machine and the exciting machine 1,100 turns per mi Boistel thinks that, by some slight modificat machine might be arranged for 6 and the 8 for 12 lights.

---

* It seems that the "horse-power" used as the unit in kilogrammetres instead of 75, which represents that used

The principle of Siemens' machines is based only on the inductive reactions produced by the passage of the spires of the multipliers before an electro-magnetic inducer, and under the influence of a tangential motion. This is not precisely the effect produced in Faraday's classic experiment, and the direction of the currents produced is even different from what it should be, according to the generally received notions of induction. I have studied in detail these different kinds of inductions in a paper presented to the *Académie* on the 24th February, and the substance of this paper will be found in Note A at the end of this volume.

We have lately visited with much interest a large establishment which Siemens Brothers have organized in Paris, at No. 8 *Rue Picot*, for the construction of those machines under the management of Boistel.

Jablochkoff's System. — Jablochkoff has also constructed an induction machine with reversed currents, and with means for dividing the light, which is intended to admit of being more easily cleaned than the Gramme machine, and to work with less motive power without becoming heated. For this purpose Jablochkoff uses for inducers a cast-iron toothed wheel, having the teeth slightly inclined to the direction of the axis, and separated from each by a rather wide space. A coil of wire winds between these teeth in the manner shown in Fig. 36, and when this is traversed by a current the teeth assume alternately opposite polarities, which convert

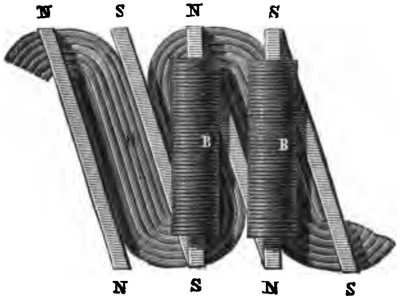


FIG. 36.

the system into a kind of electro-ma
poles, acting like Lontin's magnetic pi
system is formed of a series of stra
B B, with expanded poles, and placed p
the wheel crossing its teeth S S, N N, S S,
end they are in contact with one tooth, at
touch the next tooth. As these teeth are p
in opposite ways, it follows that for a certa
wheel the electro-magnets will be polarized
this will give rise to magneto-electric curr
which surround them; but when after leaving
different parts of the polarized teeth are bro
different parts of the induced coils, there w
these reversed polar currents and dynamic
will carry on the magneto-electric action and
in the machines of De Méritens. Thus,
constructive arrangements, a relatively pow
machine is obtained. In the form of the m
in Jablochkoff's establishment, there are 36
and these are so joined as to give three ser
each formed of 12 coils joined for quantity.
course, 36 teeth to the wheel, and under these
Jablochkoff candles are kept lighted, with a
equivalent to that of two men, but under the
induction current coming from a small Gramm
this way the current from the Gramme machin
under favourable conditions into alternately re

COMPARATIVE EXPERIMENTS ON THE EFFE BY THE DIFFERENT ELECTRO-MAGNETIC

The study of the comparative effects p
different machines suitable for the electric l

of great importance, and this has been so well understood that at various times there have been instituted experiments upon it more or less conclusive. As early as 1855 Ed. Becquerel had made an important investigation on batteries as regards this point, and the work was continued by Tresca at the *Conservatoire des Arts et Métiers* with the magneto-electric machines of the *Alliance* Company. At a later period these machines were the subject of laborious investigations, conducted by Reynaud and Degrand at the Directory of Lighthouses. A more profound study of the question was undertaken by Le Roux in 1865, and this was the subject of a very interesting communication printed in the *Bulletin de la Société d'Encouragement* (*tome XIV.*, page 699). Jamin, in conjunction with Rogers, examined from a scientific point of view the *work* produced by the same machines, and in 1877 Tresca, in a paper read before the *Académie des Sciences*, gave a complete investigation of the effects produced by the Gramme machine. At length the success of these machines, and of their application to lighthouses, so much attracted the attention of the English that in 1877 they considered it necessary to appoint a Commission of Inquiry to examine this question. This Commission was composed of Tyndall, Douglass, Sabine, Edwards, Drew-Atkings, and Minster, with Douglass as reporter; and it shortly afterwards published a Report, known as *The Report of the Trinity House on the South Foreland Lighthouse*, and this was for some time regarded as the best authority on the subject. The Americans, however, were also desirous of examining the question, and the Franklin Institute, after an invitation to the makers of machines to compete, which was responded to by only three, appointed a Commission composed of Briggs, Rogers, Chase, Houston, Thomson, Rand, Jones, Sartain, and Knight, and this Commission, subdivided into three committees, presented a double report, which was published in the Bulletin of the Franklin Institute. We shall give the numerical results from

COMPARATIVE EXPER

Notwithstanding the importance of
believe the question is far from having
find that in them the spirit of nationalit
a part that they cannot be implicitly tr
rely on the figures given by the several m
of the machines. Not only are the maj
viduals without the scientific acquireme
exact results, but there are personal interes
of which it is impossible to eliminate from
put forth, and for my part I believe that we m
great deal from the results which have been
Amidst this confusion it is difficult to see where
it is much to be desired that an international c
should undertake to completely clear up the que
the meanwhile we give the results obtained by th
and American Commissions in the two tables on p
124, and 125, and to these we shall add a third tab
up by Shoolbred, from the most recent experimen

In order to define the values of the figures in the
we must mention that the standard for light adopted
and denominated a *candle*, represents the light of a s
candle, having an intensity equal to eight-tenths of
of a *bougie de l'Étoile*. A Carcel lamp represents
candles (9·6).

In the table of English measurements mention is
the *condensed radiating power* and of the *diffused*
power. It is important that these expressions sh
understood. The condensed radiating power, as
already indicated on p. 21, is applied to the light
by a continuous current between two carbons, one
is hollowed out in a cup shape and so turned as to
reflector, and to emit the light externally with increa
illuminating power. The diffused radiating powe
which is produced by a light between two carbons
a cup-shaped hollow.

In the American table mention is made of *foo* this is the unit of moving force which corresponds with our kilogrammetre; it is equal to a kilogrammetre divided by 7·233.

The Report of the English Commission assigned the superiority to Siemens' machine (small form). According to Tyndall this form is best adapted for connecting with machines, and in proportion to its small size its effects are enormous. We must remark, however, that the figures given in the table on pages 125 and 126 for the Gramme machine, relate to machines of the pattern of 1875. Now, the new patterns of 1876 have given results infinitely superior, not only with regard to the yield of the Gramme machines tried in England, but also with regard to the Siemens machines extolled by the English Commission. According to the experiments made in France the values relating to the Gramme machine should be rectified as follows:—

With a machine weighing 175 kilogrammes, making 850 revolutions per minute under a motive power of 2½ horse-power, the condensed radiating power would be 4,297 candles, and diffused radiating power 2,590, which would give for each horse-power 1,719 for the condensed and 1,036 for the diffused radiating power; the Gramme machine would then take the first place in order of merit.

The following are the conclusions of the American Commission:—

After having carefully considered all the facts noted in the reports which have been submitted to it, the Commission has unanimously come to the conclusion that the small form of Brush machine, although in some respects less economical than the Gramme machine or the large Brush machine, for the general production of light and of electric currents, is, of all the machines experimented with, the best adapted to the wants of the Institute, chiefly for the following reasons:—

1°. It is admirably arranged for the production of currents of very different intensities, and it produces a good light.

It is remarkable f

parts of the machine is arranged, and
tors; and, moreover, it admits of being

To us it appears extraordinary tha
mutators can realize the advantages refe
and we believe that if this machine ha
the realm of scientific experiment and p
tical use, the conclusions would have
We think, too, that the question is far
America than in Europe; and this is a
several American men of science.*

---

*John Trowbridge, in the *Scientific American* of the
thus expresses himself on this subject:—

With regard to the electric light America is far behind E
the progress recently made, and unless some great invention i
in this country and sanctioned by the Patent Office, we mu
novelties here.

This inferiority exists not only in the number and variet
which have been brought before the public, but also in the
the dynamo-electric machines. We see in Europe, side by si
forms of Siemens' machines, those of Gramme, of which Schuc
is merely an interesting form, and which have been so arrange
alternately reversed currents, a condition necessary for the reg
tion of the carbons used in the electric lamps. We see al
machines, which give the same results. It seems that to ob
quantity of light less motive force is required with the foreign
American machines, and a lower velocity is required for workin
is a great advantage. . . .

America has not yet been able to produce an electric regu
as well as that of Serrin, and the foreign carbons are superio
with here. We have not yet seen the carbons metallized by
processes, which prevent their heating beyond the point of co
which have long been known in France. The Brush lamp an
lamp, the best known in America, answer well for the purpo
illumination; and in this country there are not more than a d
ments lighted by the electric light, while on the old conti
reckoned by hundreds. Nor has illumination by incandesce
in America, whether the carbons have been placed in a vacuu
gen, whether wires of platinum and iridium or filaments of pl
tos have been used. The carbons fall to pieces or crack
time, or perhaps the metal fuses. However, the two plans
menti wires, have been tried 1

he conclusions of Elihu Thompson and J. Hudson are ever, somewhat different, and in our opinion more ect. They are separately stated in this way:—

°. The Gramme machine is the most economical as a ans of converting motive force into electric currents; it ilizes in the arc from 38 to 41 per cent. of the motive work roduced, after deduction is made for friction and the resistance f the air. In this machine the loss of power due to friction nd to local actions is smallest, doubtless on account of its smaller speed. If the arc is maintained in its normal condition scarcely any heating is produced in the machine, and the presence of sparks at the commutator can hardly be perceived.

2°. The large Brush machine comes second in the order of efficiency. It produces in the luminous arc useful work equivalent to 31 per cent. of the motive power employed, or to 37½ per cent. after the friction has been deducted. It is, in fact, but little inferior to the Gramme machine, but it has the disadvantage of requiring a very high speed, and consequently there occurs a greater loss on account of friction. This disadvantage is, it is true, compensated by its power of working with a greater external resistance compared with the internal resistance of the generator, and this, in a manner, does away with the heating of the machine. It is this machine, moreover, which has given the most powerful light and the most intense currents.

3°. The small Brush machine ranks third, with a useful work in the arc estimated at 27 per cent. of the motive power employed, or 31 per cent. with deduction for friction. Although this machine is in some respects inferior to the Gramme machine, it is nevertheless admirably contrived for the production of currents of intensity, and it can be made to produce currents of very different electro-motive force. By suitably arranging this machine, the electro-motive force may be increased from 55 o 120 volts, and the currents it produces may be divided between wo circuits, an advantage, however, which is possessed by ther machines. The simplicity of the commutator and the acilities for repairs which the arrangement allows, are also dvantages to be taken into consideration. This machine, moreover, does not produce much heating.

4°. Wallace Farmer's does not yield in the working cir-so large a proportion of the motive power as c chines, because it uses up a large part of its po work and in a small space, in consequence of t been sacrificed in the production of local actions. this defect a very good machine might be made.

We regret that a machine of the Siemens type c placed at our disposal. Whatever may be its valu minations would have been of importance as sup for a machine so well known and in which the indu ture is so different as regards its principles from th other machines, and which, by the manner the wire theoretically favours the work.

Thomson and Houston point out that if it is de compare the results obtained by them with those of t lish Commission it is necessary, on account of the c arrangements of the carbons of the regulator adopte English experiments, to divide by 2·87 the numbers senting the condensed radiating power. Still the nu obtained to represent the luminous power of the Gra machine would be too great, being 438 candles, whereas found it to be only 383 candles. This circumstance indic that we cannot trust entirely to all these figures, for this v number these gentlemen have found to be too high seems us in France to be much too low. In all these Photometr measures there is evidently a sad want of agreement, whic shows that all the experiments must be repeated.

In the meantime we think that we ought to record here the results of experiments made with the Gramme machine by several French engineers and men of science whose names are a sure guarantee for their accuracy.

We shall begin with Tresca's experiments, carried out at Sautter & Lemonnier's, with two Gramme machines, the large and the small form, which, driven with a velocity of 1,274 turns per minute for the large form and 872 turns for the small form, yielded respectively light equal to 1,850 and 300 Carcel lamps. I have given in my *Exposé des applications* *d'électricité, tome V.*, p. 542, the details of these experiments, and I shall here content myself with indicating the results.

According to these experiments it would follow that the mean work in kilogrammetres per second of the large machine is 576·12, or 7·68 candles, which gives for a light of 100 Carcel lamps 0·415 horse-power; for each light per second 0·51 kilogrammetres. For the small machine this work is 210·65 kilogrammetres, or 2·81 horse-power, which gives for a light of 100 lamps 0·92 horse-power, and for one lamp per second 0·69 kilogrammetres.

"The machines," says Tresca, "worked with regularity for a time sufficiently long to show that there was an absence of all sensible heating. The work expended varied very little during the course of the different series of experiments, although one of the determinations had been made after the machine had been driven for a long time.

According to the experiments made at Mulhouse by Heilmann, Ducommun, and Steinlen, who now use this method of lighting, each of their lamps, which supplied a light of 100 lamps, required only 1·65 horse-power of mechanical force to be expended.

Experiments made by Schneider and Heilmann with several machines gave the following results:—

Description of Machine.	Number of turns per Minute.	Work expended in Horse-power.	Luminous intensity measured by Bunsen's Photometer.	Remarks on the Regulators.
Machine B ...	816	1·921	95·6	with ground glass globe.
Machine B ...	816	1·921	122·2	without globe.
Machine B ...	804	1·980	86·8	—
Machine A ...	810	1·849	85·3	—
Machine C ..	763	1·833	103·2	—
Machine D ...	883	1·360	68·7	—

These last results are less favourable than those obtained by Tresca; but we must not lose sight of the fact that he was operating under exceptional conditions, and had perhaps not taken into account the condensed luminous power. From for a light of 100 Carcel lamps may be taken from t 0·92 and 1·80 horse-power, and reckoning found by these, 1·47—a number very near that for e and Ducommun—we have 70 Carcel lamps power, with a speed of 850 rotations per minute. to Tresca's figures this would be 103 lamps, or 1,03

According to experiments made with the Ja candle in Jablochkoff's workshops, the quantity of horse-power would be represented by 23 gas-lights for the machines of De Méritens, by 28 or 30 lights for the Siemens ma machines, and by 30 or 32 lights

It will be perceived that the real value of these re by no means agreed upon; but it must also be admitt the experiments are very difficult to make on account luminous effects, which exhibit considerable difference one moment to another.

We must call the reader's attention to one importa mark that has been made on the results yielded b machines according as the light is concentrated or divi

According to the comparative experiments that have made, it would appear that a much greater motive pov required to obtain the same light when it is divided a several lamps than when it is concentrated at one point. the *Courrier des États Unis* of the 28th January, 187 read thus:—

Given a light of one lamp equivalent to 15,000 candl same quantity of light divided between five lamps inser the same circuit will be reduced to 2,000 or 3,000 candl the same motive power; in other words, it would be neces use five or six times as much power to produce a divide as to produce a single light, and this proportion will ir with the number of divisions. If, however, this principle rect, it will have its counterpart and corrective in tha principle, which also rests on a progressive scale: name by increasing the power generating the electricity beyo is necessary to produce a certain quantity of light, sa units for a single lamp, the loss by the division of the will diminish, not in direct proportion, but in progressive proportion to the excess of power employed. Thus, if 80 horse-power are required to produce 15,000 units of light at one lamp, and if the light is, by division, reduced to 200 units, 160 horse-power will produce not simply 400 units, but a much larger proportion, which will increase, not by addition but *by multiplication*, in proportion to the excess of power employed. *It is, therefore*, not impossible to obtain a divided light with a certain intensity, but on condition that the quantity of electricity produced shall be raised to a power much greater than that which will give a single light representing the same number of candles.

The question is to ascertain the proportion between the two terms, that is to say, whether the amount of power required for useful division be not out of proportion with the result obtained, or in other words, if enormous apparatus would not be required for an inconsiderable effect. This reduces the problem to the total cost of erection and maintenance. The question may be thus stated: If 80 horse-power produces a light of 15,000 candles in a single lamp, how many horse-power would be required to bring up the light to the same value of 15,000 candles when divided among several lamps?

Edison is seeking for the solution of this problem, which it would seem he has not yet found. This is the one important question. Edison has also to invent a generator of unheard-of power, and in this he says he is sure of succeeding. But in the meantime he has to try those which are at present in use, in order, no doubt, to find which comes nearest to his ideal, that it may supply the most advantageous data for constructing his own.

EFFECTS OF THE RESISTANCE OF EXTERNAL CIRCUITS.

If we were to take into consideration only the proper resistance of the conductors composing an external circuit, it is evident that the maximum of electric intensity, yielded by the generat

had the minimum resistance. But as, in
the electric light, a part of this external circu
certain resistance, this resistance becomes us
have seen that, according to Joule's law and al
to the experiments of Jamin and Becquerel, th
effect is obtained when this useful resistance is e
useless resistance, plus that of the generator. T
fore, the resistance of the arc which has to be
considered from this point of view; and it will
advantageous to diminish as much as possible the
of the conductors used for simply conveying the e
Under these conditions the loss to which the light
may take place in greater or less proportion, acc
the resistance of the generator. This is to a certa
explained by the circumstance that, the resistanc
conductors being added to that of the generator, th
tells more in the final result in proportion as the
smaller. It must, besides, be remembered that the
of the unutilized resistance of the circuit, by dimini
intensity of the electric current, diminishes the ener
mechanical resistance opposed to the motor, and by
it to acquire greater speed renders the loss of elect
sity less marked. The reverse will, of course, oc
the resistance of the circuit diminishes instead of i

The following results of some experiments ma
South Foreland will illustrate these remarks. Be
lighthouse and the building containing the machi
tance of 694 feet, there were carried for the ele
three cables, two of which were each formed of sev
wires No. 14 (Birmingham Wire Gauge), and were
constitute the circuit, thus giving a total length of
with a resistance of 0·32 of Siemens' unit, or abo
33 metres of telegraph wire.

With Holmes' machine, which had the greatest
the loss of luminous intensity was estimated at 16·1
with the Gramme machine, of much less resista

ed at 31·3 per cent. ; and with Siemens' machine,
g the least resistance of all, it reached 43·4 per cent.
sing a cable of less resistance, this loss was reduced to
er cent. with the Siemens machine, but it became 35
cent. when, by coupling two Siemens machines for quan-
, their total resistance was reduced by one-half. The
ployment of this cable of small resistance with one of the
liance machines caused a loss of 69·1 per cent. of the total
ght, and with Holmes' machine the loss became 66·1 per
nt. With two Holmes machines coupled the loss rose to
5·5 per cent. These experiments show, therefore, that in
der to realize the conditions necessary for the maximum
light, the resistance of the conducting wires must have a
rtain relation to that of the machine. (*See Note B*).

RESULTS PRODUCED BY COUPLING TWO MACHINES.

cording to the experiments made at the South Foreland
oupled magneto-electric machines, it has been found
e light produced by two coupled machines was more
than the sum of the lights produced by each acting
ly. Thus two Siemens machines having separately
ghts, the intensities of which were represented by
d 6,563 candles, supplied when joined for quantity
ual to 13,179 candles, or 19·7 per cent. more than
f the lights produced separately. This result is
ar to the Siemens machines, for the same occurs
amme machines; but with the former it is much
ed. These results are shown in the table on
nd 125. They prove that, as we have already
ge 119, as regards the luminous intensity, there is
vantage in concentrating the electric action at a
than in dividing it among several.

TABLE OF THE AMERICAN EXPERIMENTS.

RESULTS PRODUCED BY COUPLING.

NAMES OF THE MACHINES.	Weight in Pounds.	COPPER WIRES.				Revolutions of the Armature in one Minute.	Foot-Pounds of Power expended for each Candle of Light.	Horse-Power.	Light in Candles.		Foot-Pounds of Power expended for each Candle of Light.	Sizes of Carbons.	Length of Carbon consumed per Hour.	
		Of the Armature.		Of the Magnetic System.										
		Size.	Weight	Size.	Weight				Total.	Per Horse-Power			+	–
		in.	lbs.	in.	lbs.							in.	in.	in.
Large Brush ...	475	·81	32	134	100	1,340	107·606	3·26	1,230	377	87·4	⅜ × ⅜	1·78	0·34
Small Brush ...	390	·63	24	96	80	1,400	124·248	3·76	900	239	137	⅝ × ⅝	1·91	0·58
Large Wallace.	600	·42	50	114	125	800	–	–	823	–	–	–	–	–
Small Wallace.	350	·43	18¾	98	41	1,000	128·544	3·89	440	113	292	¼ × ¼	2·45	0·075
Gramme.........	366	·59	9½	108	57½	800	60·992	1·84	705	383	85	¼ × ¼	3·15	0·55

THE ENGLISH EXPERIMENTS.

Total Luminous Intensities.				Luminous Intensities for each Horse-power of Force absorbed.				Classification of the Machines in order of Merit.
Condensed Light.		Diffused Light.		Condensed Light.		Diffused Light.		
Candles.	Carcel Lamps.	Candles.	Carcel Lamps.	Candles.	Carcel Lamps.	Candles.	Carcel Lamps.	
1,523	217·57	1,523	217·57	476	68·00	476	68·00	6
1,953	279·00	1,953	279·00	543	77·57	543	77·57	5
6,663	951·86	4,016	573·71	1,257	179·57	758	108·29	4
6,663	915·86	4,016	573·71	1,257	179·57	758	108·29	4
14,818	2116·86	8,932	1276·00	1,512	216·00	911	130·14	3
5,539	791·29	3,339	477·00	1,582	226·00	954	136·29	2
6,864	980·57	4,138	591·14	2,080	297·14	1,254	179·14	1
2,811	401·57	2,811	401·57	432	61·71	433	61·71	—
11,396	1628·00	6,869	981·29	1,085	155·00	654	93·29	—
14,134	2019·14	8,520	1217·14	2,141	305·86	1,291	184·43	—

TABLE OF NEW EXPERIMENTS

	Number of Candles for each Light measured horizontally.		Revolutions per Minute.	Lamps used.	Nature of the Motor.	Engines.		
							Cylinder.	
	Total.	Per Horse-power absorbed.				Revolutions per Minute.	Diameter in Inches.	Strokes in Inches.
Holmes	1,523	476	400	Holmes	Steam	—	13	18
Alliance	1,953	543	400	,,	,,	—	—	—
,,	3,000	667	400	Serrin	,,	—	—	—
Méritens, large	8,600	1,228	650	Holmes	Gas	156	9	16
,, small	1,860	1,240	880	Duboscq	,,	156	9	16
Siemens, medium	4,100	1,254	850	Siemens	Steam	—	13	18
,, ,,	—	—	—	,,	Gas	158	9	16
,, small	—	—	—	,,	,,	155	9	16
Gramme, for a single light, (A)	960	320	—	Serrin	Steam	115	—	—
,, ,,	1,824	730	920	,,	,,	—	—	—
,, ,,	2,850	1,018	892	,,	,,	—	—	—
,, ,,	2,520	740	830	,,	Gas	143	6¼	12
,, ,,	705	383	800	Brush	Steam	—	6	8
Large Brush	1,230	377	1,340	,,	,,	—	6	8
Small ,,	900	239	1,400	,,	,,	—	6	8
Large Wallace	823	—	800	,,	,,	—	9	18
Small ,,	440	113	1,000	,,	,,	—	6	8
Gramme Division Machine, 16 lights	250	—	640	Jablochkoff	,,	—	—	—
Gramme Division Machine, 20 lights	—	—	650	,,	,,	142	10	13
Lontin Division Machine, 6 lights	570	—	350	Serrin-Lontin	,,	110	9½	13½

DRAWN UP BY SHOOLBRED.

Engines.			Remarks.		
Horse-power per Light.					
NOMINAL.	EFFECTIVE.		Localities.	Observers.	Observation
	Total.	Absorbed.			
10	—	3·2	South Foreland	Douglass	Alternatin Magneto Electric Currents.
10	—	3·6	,,	,,	
—	—	4·5	Paris	Allard	
8	10·9	7·0	Royal Institution	Douglass	
8	4·2	1·5	,,	,,	
10	—	3·3	South Foreland	,,	
8	8·9	5·4	London Stereoscopic Co.	Amos	Dynamo Electric Machines w Continuoı Currents
8	8·2	4·7	,,	,,	
12	3	2·7	La Chapelle, Paris	Chemin de fer du Nord	
—	—	2·5	Rouen	Powell	
—	—	2·8	Paris	Tresca	
3·5	5·1	3·4	Edmundson, Westminster	Shoolbred	
—	—	1·84	Philadelphia	Committee of the Franklin Institute	
—	—	3·26	,,	,,	
—	—	3·76	,,	,,	
—	—	—	,,	,,	
—	—	3·89	,,	,,	
20	--	1·25	Avenue de l'Opéra, Paris	Allard	Dynamo-Electric Machines w Alternatin Currents.
20	—	—	Thames Embankment	,,	
9	—	—	St. Lazare Station, Paris	Chemin de fer de l'Ouest	

FOR EVOLVING THE ELECTRIC LIGHT.

ced between carbon electrodes.—We ning of this work that the electric light was passage of an electric discharge or current us or solid body having a conductivity suffi- become incandescent from the enormous by the passage of the electricity. We saw r to obtain this light under the most favour it is necessary to use electrodes made of sub- of disintegration, and of ready combustibility, substances carbon is that which yielded the

vho first conceived the idea of using carbons r producing the voltaic arc, but these carbons charcoal quenched in water. These were, ckly consumed that other physicists endea- itute a more durable form of carbon for the Foucault was the first to make use of that which is deposited in the inside of the retorts as-making. He thus obtained a voltaic arc r durability.

owever, much that was objectionable in retort- ant of uniformity and from its admixture with which caused the light produced to be far The carbons were destroyed also in conse- fusion of the siliceous matter contained in nerally emitted vapours which, being better n the arc, carried off a portion of the current ous discharge.

at by suitably choosing these carbons, and by rom the uniform portions of the deposits, good obtained; but thi has long been objected to, and has often proved an obstacl to the applications of the electric light. Yet even at th present time, and in spite of the progress which has recentl been made in the preparation of carbons for the electri light, there are some who prefer the retort-coke.

The above mentioned inconvenience of retort-carbons as may readily be supposed, soon caused physicists an manufacturers to seek a method of preparing them of a pure chemical composition, and with a more uniform physica constitution. By certain processes of which we shall presently speak, this has gradually been achieved. Into th composition of these artificial carbons certain metallic salts have sometimes been made to enter, in order that, under th threefold influence of the electrolytic, the calorific, and the reducing actions, the metals of the salts might be deposited on the negative pole, where their combustion in the air would increase the light of the arc itself. Carré, Gauduin, and Archereau have made experiments of this kind, which we shall describe farther on; but the results have not been entirely satisfactory, as the light has generally been rendered flickering and unsteady. The simple carbon has therefore commonly been preferred.

The resistance of the carbons is very variable. When they are of uniform section and quality the resistance is, of course, dependent on their length or thickness. Experiments made at Silvertown by Hospitalier and Robert Gray have shown a resistance of 3·25 ohms per lineal metre for Carré's carbon of 4 millimetres diameter. A copper conductor of the same dimensions would have a resistance of only 0·001315 ohm, and therefore the copper conducts 2,471 times better than the carbon. These figures may occasion surprise, but it should be remembered that they relate to carbons of small diameter, and that, if referred to carbon of 1 centimetre in diameter, the resistance is not more than 0·52 ohm, or about 50 metres of telegraph wire.

or the electric light, made of a mixture of pounded sugar, which, after having been moulded and compressed, was baked, then steeped in a con- solution of sugar, and heated again to whiteness. rs afterwards, in 1849, Leonolt patented carbons ne purpose, made of two parts of retort-coke, two rood charcoal, and one part of liquid tar. These s were mixed into a paste, then subjected to power- ression, afterwards covered with a coating of sugar- d left for 20 to 30 hours at a high temperature. e afterwards purified by successive immersions in acassagne and Thiers conceived the idea of purify- s of carbon by steeping them in fused caustic, r soda. The object of this operation was, accord- e author, to change the silica contained in the carbon ble silicates. They were then steeped a few moments g water, and afterwards exposed to a current of in a porcelain tube heated to redness, in order to the earths left unattacked by the potash or soda into chlorides of silicium, calcium, potassium, iron, &c. time after these experiments Curmer proposed to bons by the calcination of a mixture of lamp black, and turpentine, the whole moulded into a cylindrical The decomposition of these substances left a porous hich was saturated with resin or syrup, and again l. These had little density and a low conducting but they were very uniform and free from all im- .

greatest success was, at the period we are speaking of, ed by Jacquelain, formerly the chemist of the *École* *le.* Experiments on the electric light made with his ns for the French lighthouse authorities were so con- e that the problem was supposed to be solved. In ection with these experiments I cannot refrain from g here a letter written to me in 1858 by Berlioz, at that manager of the *Alliance* Company, a man of intelli-

gence, who was then most enthusiastic as to the
tained by his machines :—

I ought to have written sooner to tell you
machine . . . : it works perfectly well and with increasing
we have an *admirable light.* I wanted to tell you of
I consider of consequence, for, as usual, we have to
for this important matter. You induced me to see
about his pure carbon coke, and this coke gives a st
without flame, and of remarkable brilliancy. I am
are not here, as you have been kind enough to bestow
care upon our machine. This evening I am showing
to my superintending committee. We are able at a d
60 metres to read very small writing, and no doubt
read at nearly a kilometre if space permitted. We
magnificently illuminated the dome of *Les Invalides*
about 300 metres from our apparatus; but I hope we
perform the experiment on the Seine in a steamboa
advised.

Thus with our machine taking the place of the vo
with the Jacquelain carbons, a regulating mechanism
alternately contrary currents, and a good reflector, the p
electric lighting on sea-going ships will be completely

Jacquelain's Method.—To obtain a pure carbon
lain makes use of the carbides of hydrogen, eith
obtained in the distillation of coals, shales, turf, &c
numerous products formed during the carbonization
combustibles in close vessels, or those represented
heavy coal, shale, or turf oils, or by volatizable orga
stance.

"These organic materials," says Jacquelain, "contai
cast-iron receptacle, are introduced into a cast-iron bo
lower level by a conducting pipe furnished with a coc
boiler is also provided with a cock for emptying it. The
are carried by a cast-iron pipe into a horizontal retort
refractory earthenware, and fitted with a screen for re

ny obstruction in the retort is removed by From the last receiver which forms the e inverted U, a curved pipe leads the hydro- ecomposed volatile products under a grating."

his process was very incomplete, and offered ie quality of the products. Along with ex- giving very satisfactory results there were , and sometimes even worse than those ob- tort-coke. Therefore Carré determined to lem afresh, and he thus speaks of it in the s *de l'Académie des Sciences* of the 19th February, :—

Method.—"The superiority for various experi- tificial carbons, and the possibility of purifying by ds, aqua-regia, &c., the carbonaceous powders into their composition, then led me to seek for ns of producing them economically. By moistenwders either with syrups of gum, gelatine, &c., or oils thickened with resins, I succeeded in form- sufficiently plastic and consistent to be forced into rods through a draw-plate placed at the bottom of a compression apparatus under the pressure of about spheres. Carbons are now manufactured by this I have at various times presented some of them *démie des Sciences* and to the *Société d'encouragement.*

carbons have three or four times the tenacity and are rigid than retort-coke carbons, and cylinders of 10 diameter may be used of a length of 50 centimetres danger of their bending or crossing during the breaks which often happens with others. They may obtained of the slenderest diameters (2 millimetres)

s chemical and physical homogeneity gives great steadi- ay luminous arc; their cylindrical form, combined with irc their composition and structure, causes their

in a lathe, and therefore there are no occultations of t
maximum light like those produced by the projecting
paratively cold corners of the retort-coke carbons. Th
liable to the inconvenience of flying in pieces when fir
as the others are, in consequence of the great and s
pansion of the gas contained in their closed cellula
which are sometimes 1 cubic millimetre in capacity.
them one and the same uniform density they are cons
the same amount for an equal section; they are mu
conductors, and, without the addition of any substan
than carbon, they are even more luminous in the prop
1·25 to 1."

The preparation preferred by Carré is a mixture
dered coke, calcined lamp black, and a syrup mad
parts of sugar and 12 parts of gum. The following
is given in his patent of the 15th January, 1876:—

Very pure coke, finely powdered	... ...	15 pa
Calcined lamp black	... ...	5
Syrup of sugar	... ...	7 to 8

The whole is well pounded together, and from
parts of water are added to make up for the loss by e
tion, and to give the required degree of consistenc
paste. The coke is to be made with the best samples
and purified by washing. The paste is then compress
passed through a draw-hole, and the carbons are afte
piled in crucibles and exposed for a certain length
to a high temperature. Details of the operations for
ing these carbons will be found at page 54 of H. Fon
work.

We may add that Carré, being desirous of impart
the electrical light the hues most suitable for theatrica
poses, has succeeded in so treating his carbons tha
impart to the light a tint which, instead of being
white, has a rosy-yellow hue, that is very advantageo
bringing out the complexions of the actresses.

Carré's manufacture has, since the great experiments

chkoff Company, been much exter
large scale on which his process is be
ow send out carbons 50 per cent. bet
carbons are now at a price which all
and this circumstance greatly cond
of the applications of the electric li
System.—The carbons manufactured
carbon, their base being lamp bla
this substance is comparatively hi
is difficult, Gauduin was obliged
rce of carbon, and he obtained it b
ssel common rosin, pitch, tars, resir
l artificial oils, essences, or orga
decomposition by heat, leave suff

oducts are put into crucibles and hea
e volatile matters being conducted
amber, whence they are carried by a
the condensed liquids, such as tars
les of hydrogen, into another worn
ollected for use in the manufacture o
ains in the retort some more or less
h is pulverized as finely as possible,
ne or mixed with a certain quantity
of the carbides of hydrogen obtaine

prepared, these carbons are comple
are superior to those met with in cc
his carbons the inventor uses steel
s
anding the highest pressure of a pow
The moulds are arranged like draw-
ent has been much improved by Ga
the sticks are supported througho
o that they do not break by their
pens with ordinary draw-plates.
recently Gauduin has further impro

Instead of carbonizing wood and reducing the charcoal t powder, he selects a suitable piece of wood, which he cut to the shape required in the carbon; then he converts into hard charcoal, and finally soaks it, as in the manufactu we have described. The heating of the wood is conducte slowly so as to drive off the volatile matters, and the final he ing takes place in a reducing atmosphere at a very high te perature. All impurities are removed from the wood b preliminary washing in acids and in alkalis.

Gauduin also points out a method of stopping the p of the wood by heating it to redness and exposing it to action of chloride of carbon and various carbides of hydro He expects thus to produce electric carbons which w very slowly consumed and will give a light absolutely st

These carbons have not, however, done what was exp of them, therefore they have not become general, a little used except by the firm of Sautter and Lemonni the present time it is difficult to obtain them, and it is ful if they can compete with those of Carré, who em his raw material a very cheap substance, namely co

Effects produced by the addition of Salts to the Carbons prepared for the Electr —As we have already seen, page 129, attempts h made to obtain some advantage by associating th with metallic salts, which might supply, independe voltaic arc, a light due to the combustion of the me to the negative electrode. The following experi been undertaken by Gauduin, Carré, and Archere

Gauduin mixed the following substances wit carbon:—phosphate of lime from bones, chloride borate of lime, silicate of lime, pure precipitated nesia, borate of magnesia, alumina, silicate of alu proportions were so calculated as to leave 5 per c after the carbons were dried. They were subm action of an electric current always in the san supplied by a Gramme machine sufficiently powe

of 10 to 15 millimetres long. The following
obtained :—

phosphate of lime was decomposed, and the re-
ium burnt in the air with a reddish flame; the
red by the photometer was double that given by
carbons of the same section. The lime and the
acid were, however, diffused in the air, producing
e.

chloride of calcium, the borate, and the silicate,
decomposed. But the boric and silicic acids
escape the action of the electricity by volatilizing.
vas less than with phosphate of lime.
a made the carbon worse conductors, and dimi-
light; it also fused and was volatilized without
omposed.

gnesia, borate and phosphate of magnesia were de-
, and the magnesia vapour passing to the negative
t in the air with a white flame, which much in-
he light—less so, however, than the lime salts.
, boric, and phosphoric acid were diffused in the
oke.

mina and silicate of alumina were difficult to de-
; a very strong current and a considerable arc were
. Under these conditions the aluminum was seen
n vapour from the negative pole like a jet of gas,
rn with a bluish little—luminous flame.

au found that the introduction of magnesia into
ns increased their illuminating power in the pro-
1·34 to 1.

ng to Carré it would seem—

potash and soda doubled at least the length of
dered it silent, and, by combining with the silica
ent in retort-coke, they eliminated it in the state
nt, vitreous, and often colourless, globules at 6
tres from the points. The light was increased
tion of 1·25 to 1;

2°. That lime, magnesia, and strontia increased the lig the proportion of 1·30 or 1·50 to 1, giving it different col

3°. That iron and antimony brought up the increa 1·60 and 1·70;

4°. That boric acid increased the duration of the car by covering them with a glassy coating which protected from the air, but without increasing the light;

5°. That the impregnation of pure and regularly pc carbons by solutions of various substances is a convei and economical means of producing their spectra, but preferable to mix the elementary substances with compc carbons.

Metallized Carbons.—According to E. Reynièr, carbons being consumed a little by combustion on t lateral surfaces, which glow for a length of 7 or 8 millime above and below the luminous point, there is a complete as regards the light, and it would be an advantage to cc them with a metallic covering in order to avoid this lat combustion. It follows, in fact, from his experiments in workshops of Sautter and Lemonnier with a Gramme mach of the 1876 form, that the metallized carbons are consum less than the ordinary carbons, as the following results show:

Dimensions of the Carbons.	State of the surface of the Carbons.	Length of Carbons used in one Hour.			Photometric Measures
		At the + pole.	At the — pole.	Total.	Ga Jet
d = 7 mm. S = 0·3846 sq. cm.	Uncovered	166 mm.	68 mm.	234 mm.	94
	Covered with copper	146 ,,	40 ,,	186 ,,	,,
	Covered with nickel	106 ,,	38 ,,	144 ,,	91
d = 9 mm. S = 0·6358 sq. cm.	Uncovered	104 ,,	50 ,,	154 ,,	52
	Covered with copper	98 ,,	34 ,,	132 ,,	553
	Covered with nickel	68 ,,	36 ,,	104 ,,	516

nts," he says, "were made with Carré car- lamp. It was observed that with naked e smallest diameter had the longest points, n expected; but with the metallized carbons e case, a circumstance difficult to explain. vever, conclude from these experiments :— lependently of the improvement in the shape of bon, covering it with nickel lengthens the duration . of the carbons of 9 millimetres, and by 62 per the 7 millimetre carbons. Covering with copper ; the duration by an amount intermediate between ked and of the nickelized carbons;

with equal sections the metallization of the s not seem to modify the amount of light yielded

the luminous power of the carbons of small diameter erior for the same electric intensity to that of car- diameter, which is explained by the fact that con- es placed in a circuit composed of conductors of or of high conductivity become the more heated as is smaller; and also from the fact of the polariza- more energetic, the smaller are the carbons. This entrates the resulting calorific effects of which we above. It depends also upon the circumstance, the maximum of light it is necessary that the re- circuit of the voltaic arc should be as nearly as f the generator; he metallization by allowing carbons of small e section to be used for the same time of action, eous results. This metallization is effected gal-

to A. Ikelmer, this system of metallization can ntage except in so far as it may lessen the re- e carbons, and as the thin layer of metal is ne influence of the high temperature and disin- distance that may reach as much as 10 centi- provement of the conductivity cannot in this ned, any more than the prevention of lateral

Consequently, he thinks that the problem would be solved much better, at least so far as increased c ductivity is concerned, by connecting with metallic r These rods may be placed either within the carbons themsel or in the electric candles on both sides of the insulator, a thus they may become heated without danger of oxidati Jablochkoff, who had patented this system of rods as ea as November, 1878, finds them advantageous only so far they lessen the consumption of the electrodes; and if inste of a covering of carbon use is made of a covering of m nesia and an iron rod, as in the preparation of these candl the consumption might be reduced to one-eighth. But t result is obtained at the expense of the brilliancy of the lig produced, which is then reduced to that of six or eight g jets. Nevertheless, as there are cases where there is an a vantage in increasing the duration of the candle at the c of the luminous intensity, he has patented this system wi the idea of using it in Russia for lighting carriages.

Effect of heat on the conductivity of the carbon—Heat is known to modify the electric conductivity bodies, diminishing that of metallic conductors, and usuall increasing that of substances of mediocre conductivit whether liquid or solid;* and carbon is precisely one o these.

According to the researches of Borgman, the temperature of a carbonaceous substance heated to orange-red decreases its resistance in the following ratio :—

For wood charcoal	0·00370—	between	26°	and	260°
For Dormez anthracite ...	0·00265—	”	20°	”	260°
For Alibert plumbago ...	0·00082—	”	25°	”	250°
For coke	0·00026—	”	26°	”	275°

It would seem that even a feeble calorific radiation causes a diminution of resistance in plates of wood charcoal, and that between 100 and 125 degrees the resistance of pinewood, elm, and ebony charcoals notably varies.

---

* See my paper on the conductivity of mediocre conductors, p. 27.

Light produced by means of conductors of indifferent conductivity.—We have said at the commencement of this chapter, that one of the means of producing the electric light is the heating which takes place when a powerful current traverses a body of indifferent conductivity interposed between two electrodes of good conductivity. We have also seen that rods of carbon and of refractory substances constitute these bodies of indifferent conductivity, and that Jablochkoff on one hand, and Lodyguine and Kosloff on the other, had made some very interesting experiments on this subject. It is this new method of producing the electric light that we are now about to consider, and we shall begin by Jablochkoff's system, which is the most curious.

Jablochkoff's System.—In this new system the induction currents from a Ruhmkoft's coil of moderate dimensions are used, and a piece of slightly baked kaolin, two millimetres thick and one centimetre wide, which forms the semiconducting substance, is required to supply the incandescent point, or rather the luminous source, for the whole appears to be illuminated. With a single coil two sources of light can easily be obtained in one circuit, but by increasing the number of induction coils and the power of the generator, the number of these luminous sources may be indefinitely increased—a circumstance which may in some degree solve the difficult problem of the division of the electric light. We shall, however, consider this question farther on.

The arrangement of the system is very simple; the small piece of kaolin is introduced between two little iron nippers which form the polar electrodes, and which are themselves attached to two clips capable of moving horizontally by means of a screw. These nippers seize the piece of kaolin by its upper slightly thinned edge, and even a little beyond this edge, in order that the apparatus may be more easily lighted; for this apparatus must be lighted, and it will readily be understood that the substance is not of itself sufficiently

conductive, even of induced curren
passing a current able to produce th
remedy this defect of conductivity, the
be warmed in the neighbourhood of th
is done in a very simple manner, by cor
clips mentioned above by a rod of ret
taking a spark from one of the clips th
transmits its heat to the neighbouring
which fuses and affords a passage to th
at first through a very short space (1 or
over one progressively longer in propo
is moved along the kaolin, and which
the whole length of the latter when the
the second iron clip. The current th
of fused matter which is progressively
itself to the eye as a band of dazzling li
wider than it really is on account o
must be taken to concentrate the he
carbon by means of a reflector of refr
may consist of a plate of kaolin. The
as I have already said, very steady, ve
softer than the arc light. Its power d
the resistance of the circuit and on th
points interposed, but with a weak ele
to one or two gas-jets.

Kaolin appears to be the best sub
prepared as a paste, it can be made v
other substances are capable of produ
magnesia and lime have indeed given

---

* The conductivity of this kaolin, studied by
in my researches on substances of mediocre co
the passage of the voltaic current produced by
when the specimen had remained in a cellar f
it was kept in an inhabited apartment it gave r
heated to redness in a spirit-lamp it gave a de
is therefore necessary in order to obtain the im
tioned, that the electricity of tension should

resting circumstance was discovered in the ex- de by Jablochkoff, and that is, that the currents he induction apparatus intended for the light antageously exerted by a magneto-electric gene- alternately reversed currents, such as those he *Alliance* Company or the *Lontin* Company. generator, the induction apparatus does not re- condenser or an interrupter, and the intensity t is increased by the suppression of these. On d the tension is notably diminished, for in ex- have witnessed, the spark was hardly 2 milli- but in order to obtain calorific effects, tension ecessary, and we have seen that in this respect ave left nothing to be desired. Thanks to this nkoff induction machine can supply the electric is result is of the more importance that a regu- ight is not required to render it steady, and that tion of kaolin is almost insignificant (1 milli- ur). The magneto-electric generator itself need rful, and it may, as we have already said, be pro- the number of luminous jets desired, care being nect a suitable number of induction coils having wires not too thin.

illumination of a long strip of kaolin is required fluence of a very powerful current, it becomes order to light it to mark a line of lead on the f the bad conductor from one electrode to the current is at first conducted by this streak, but heating the kaolin and in producing the effects cribed. This arrangement enables a large quan- to be obtained in a small space, for in order to effect it suffices to fold the strip several times on electric multiplier.

---

its passage, be accumulated within the very substance of the and should be transformed into heat by not being able to enough as an electric charge.

According to Jablochkoff, the luminous intensity different sources varies according to the arrange dimensions of the coil, and the number of lights i in the circuit of each coil. They may therefore be so as to supply light of different intensities from their light of 1 or 2 gas-jets up to a light equivalent to

> "In this system," says Jablochkoff, "the method of d of the circuits is in fact reduced to a central artery r by a series of anterior wires corresponding with th helices of the different coils, and with as many *partial* there are coils; these last circuits corresponding with t wires of the coils, and ending separately at the differen foci which are to be maintained. Each of these foci i perfectly independent, and can be extinguished or lig rately. Under these conditions the distribution of the becomes very similar to that of gas, and I have been a 50 foci simultaneously illuminated with different inter

Jablochkoff has lately rendered more practical t we have just described by causing the current su the small pattern of the magneto-electric *Allianc* to act directly. In order to impart more tensi currents he adopts a condenser of rather large surf of the wires going from the machine to each appara condenser is composed of sheets of tinfoil, india-ru varnished silk, alternated and folded as in the En densers for submarine cables. In this way, with a t densing surface of 200 square metres, seven point may be obtained instead of two, and what is more the increased effect is produced even with curren nately reversed. The arrangement of this system is very simple; one of the armatures of each condenser nected with one of the two wires of the machine, a second wire of this machine is connected with one clips of each light apparatus, while the other clip corres with the second armature of each condenser. There i produced within each condenser successive fluxes of

ie contrary electricities, which, by charging the
, cause the illumination of the plates of kaolin, on
iks of black lead extend from one clip to the other.
ıe and Kosloff's System.—Of the various methods
btaining luminous effects by the narrowing of
ı of a good conductor, that contrived by Lody-
Kosloff had given some very interesting results
lts even made some noise in 1874, for the effects
r similar to those we have just mentioned; but in
roduce them a much greater electrical force was
ınd the portions of the apparatus brought to a
being made of retort-coke of very narrow section,
sent the desired conditions of solidity and stability.
system these little needles of carbon were cut out
prisms of at least 1 centimetre across, and were
een two insulated clips connected with the two
f the circuit, as in Jablochkoff's system.* In
revent their combustion they were enclosed in
from air, or simply hermetically sealed, so that
ı of the enclosed air should not be renewed.
verful *Alliance* machine four luminous foci could
e obtained in this way, and the lighting power was
actory. Unfortunately these carbons were fre-
ken, and it was quite a task to replace them. To
s inconvenience several ingenious arrangements
ted, of which we shall speak farther on; but all
ms have scarcely yielded anything very satisfactory
ctical point of view.

ıder rod of carbon was in fact consumed parti-

---

that the connection of the carbons intended to become
the wires of the circuit was one of the difficulties which
guine and Kosloff. In fact, by making the wire penetrate into
ıe latter was broken, on account of the difference of the ex-
metal and that of the carbon, and again the metal by touch-
f the carbon heated to whiteness was melted. Kosloff, after
ıents, has, it appears, avoided these difficulties by using a
to form the supports of the carbon rods.

cularly in the middle, and it was observe
showed a notable part of the carbon to
hence a considerable loss in the strip of ca

Edison's System.—In the year 1845 D
voured in America to take advantage of
of a platinum wire, rolled in a spiral fo
electric light, and in 1858 there was muc
invented by De Changy, which was merel
Latterly Edison has taken up the notio
noise about it in the newspapers great en
considerably the shares of the gas com
system, besides lacking novelty, only very
the problem, and in the chapter on inc
lamps will be seen the means he used, n
electric light, for everybody knew that, b
platinum spirit from melting when the int
exceeded the melting point of platinum.†
also invented a kind of regulator for the san
is more complicated, and makes the app
incandescent electro-magnetic lamp. We
these methods of electric lighting founde
effects of incandescence leave much to be

---

* In the *Comptes rendus de l'Académie des Sciences de*
1858, it will be seen that Jobard, of Brussels, had announce
that De Changy had just solved the problem of the divisibi
light by help of the incandescence of platinum spirals. (Se
applications de l'électricité, t. IV., p. 501, 2me édition.)

† It appears, according to some American newspapers, tha
marvellous discovery of Edison is not serious. Here is what
New York Herald of 5th Jan., 1879:—Mr. Edison has rece
Electric Light Company 100,000 *livres* in order to continue his
He has already spent, it is believed, 76,000 *livres* up to the
and he has yet produced nothing but promises; but it may
certain that none of these will be fulfilled, and that no importa
as regards the electric light will come from Menlo Park for the n
at least if one may judge by the present rate of progress.
done there will depend in a great measure on the conclusion
after all the researches and experiments conducted in the who
results of which are continually sent to Mr. Edison.

believe those to be preferable in which combustion and the voltaic arc are united to incandescence. We shall see that in the systems of Reynier, Werdermann, &c., the results are in fact much more satisfactory.

Systems of É. Reynier, Werdermann, and others.—By the beginning of the year 1878 Emile Reynier, struck by the advantages which incandescent effects offered for the ready production of the electric light, and especially for its subdivision, bethought himself of combining these advantageous effects with those of the voltaic arc, and for that purpose he arranged the carbons of the King or Lodyguine system in such a manner that they might burn and furnish at the point of contact a small voltaic arc resulting from the repulsions produced by contiguous elements of the same current, as in the case of Fernet's and Van Malderen's regulators. He therefore arranged above a large fixed carbon a very slender rod (about 2 millimetres diameter), which was supported vertically by means of a heavy holder, and he connected this carbon with the current at a suitable height above the fixed carbon, so as to give a bright incandescence to the thin carbon. And by this arrangement as the thin rod of carbon was consumed at the point of contact with the large carbon, it was renewed by a progressive advance produced by the weight of the holder. From this combustion, however, ashes were produced, which accumulated round the point of contact, and therefore he arranged the apparatus so that the large carbon might by a rotatory movement cause the ashes to fall off. Under these conditions Reynier was able to light 5 lamps with the current from a Bunsen battery of 30 cells, and he was even able to keep one of the lamps lighted for more than a quarter of an hour with the current from a Planté polarization battery of 3 elements. Some time afterwards the same idea was taken up by Werdermann, who used an arrangement the reverse of Reynier's. The stick of carbon was pushed upwards by a counterpoise, and thus the large carbon did not require to be moved. According to him this plan gave very good results, anc plating Gramme machine arranged for qu to light in 10 derived circuits 10 lamps giving a light equal to 40 candles.* T made on this occasion on the influence e: of carbons of different diameters, being regards the present question, we here giv presented to the *Académie des Sciences* on 1878:—

"When the electric arc is produced be the same section," says Werdermann, "th extremities take place thus: the positiv whiteness takes the shape of a mushroom, i form, and is consumed twice as fast as t The latter, which is only heated to rednes slowly shaped into a point, and the lengt portion to the tension of the current.

"Things do not pass thus if a different electrode. When the section of the positiv lessened, and that of the negative electr heat seen at the point of the latter dimi whilst the heat of the positive electrode to the reduction of the section. The elec passes over the space between the elec facility, and in order to maintain the vol must be brought nearer together.

"A strange phenomenon then appears; electrode enlarges considerably, and the dency to equalize the two surfaces, that i positive electrode as much as possible th negative. The greater the difference betw carbon, the more must the distance betwe and to avoid too great a swelling of the p tension of the current must be a little red done by using a Gramme machine, with whi current is proportional to the speed, the resistance of the coil being constant.

---

* According to Werdermann, the machine require yield this light. But I am informed that this is inc greater force must be taken into account.

"We thus reach a limit where the distance between the electrodes becomes infinitely small, that is to say when the electrodes are in contact. This is when their sections are nearly as 1 to 64; then the negative electrode scarcely gets heated, and it is therefore not consumed. Under these conditions it is only the positive electrode which is consumed, while it produces a beautiful absolutely fixed white light so long as the intimate contact between it and the negative electrode is maintained. It is in reality a light produced by an infinitely small voltaic arc.

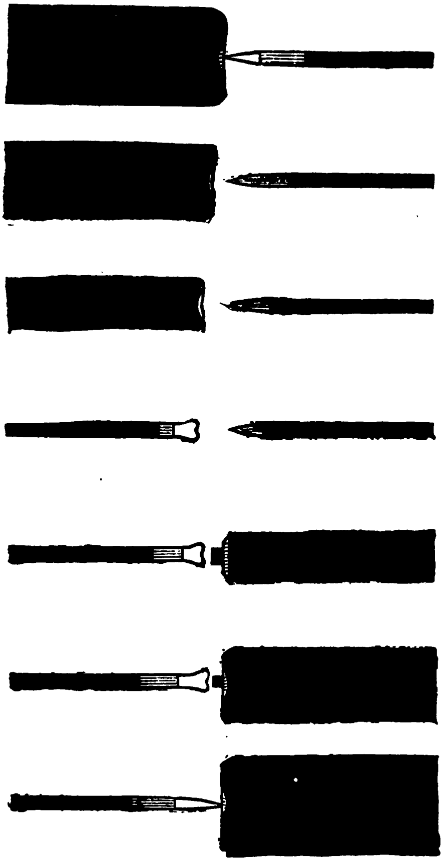
When the reverse method is adopted, that is to say, when, instead of lessening the section of the positive electrode, the section of the negative is gradually reduced, and the section of the positive increased, the light of the latter is seen to gradually diminish, and the heat of the negative electrode to increase.

"When the sections of the electrodes are nearly as 1 to 64, and they have been placed in contact, no light is any longer given off by the positive electrode; the negative one alone produces the light. It is curious that when a voltaic arc is set up between the two carbons, the smaller electrode is always shaped into a point, whether it be positive or negative."

Fig. 37 represents the series of changes in the form of the electrodes when their respective dimensions are made to vary. The electrodes in the centre represent the ordinary electrodes of equal section. In the three systems on the left are shown the effects produced as the lower electrode, which is the positive one, increases, and the three on the right show the effects of a successive increase of the upper and negative electrode.

As we have seen, Werdermann has been able by derivation to obtain with an electroplating Gramme machine the lighting of 10 electric lamps. The resistance of the coil of the machine was 0·008 ohm, and the electro-motive force was equal to that of 4 Daniell cells, with a speed of 800 turns per minute. At this speed the current corresponded with 66·06 webers; but with a speed of 900 turns it corresponded

with 88·49 webers. Nevertheless, with the 10 la
by Werdermann the velocity of 800 turns was



According to Werdermann, the resistances
were :—

For one lamp ... ...
For five lamps ... ...
For six lamps ... ...

It is surprising that with a current having so little tension such results could be obtained, and some sceptical persons would at first have denied the fact, contending that in order to obtain a focus of electric light an electro-motive force equal to that of at least 30 Bunsen cells was required; but such persons did not observe that with incandescent lamps there is no appreciable solution of continuity in the metallic circuit, and that a source of electricity of quantity suffices to produce incandescence in such a circuit. If from the resistance of a light circuit, four or five thousand metres of telegraph wire be taken away, together with the nearly equivalent resistance of the battery, and that of the electro-magnetic apparatus of the regulator, it may be understood how an electro-motive force equal to that of only 4 Daniell cells can produce effects of incandescence in a circuit of extremely small resistance, and even produce several points of light, by derivations from the current, since the total resistance of the circuit is then in a manner diminished proportionably to the number of derivations. We are not sufficiently familiarized with effects of this kind, and mistakes are often made by confounding phenomena that are produced under very different electrical conditions.

Light produced by means of an inductive action.—A short time before his death, Fuller, who had been one of Edison's fellow labourers, invented a system of electric lighting, on which we think it right to say a few words, although it appears to us scarcely practical. Here, however, is the description of it given in the *Telegraphic Journal*:—

In this system the principal current does not produce the light, but it engenders another current in a series of induction coils, and each lamp is lighted by the current of one of the coils. An alternating current must be used. The induction coils were constructed as follows:—Two magnetic cores, placed parallel to each other, were magnetically connected at one end. Round the centre of each of these cores was a

head of soft iron, and at a suitable distance a he
sulating substance. The external extremities of
were covered with insulated copper wire, and were
together, as well as to the principal wire (or to the
in such a manner as to produce two opposite magn
Between the soft iron heads and the coils spiral
wire were wound, the fineness depending on the
quired.

To one of the iron heads an iron arm was joint
of turning and being applied to the other head
magnetically connecting the N. and S. poles.
thus arranged, if a current is sent through the pri
and quickly reversed in the opposite direction, th
of the magnetic cores will change, and these
produce an induced current of high tension in
coils; this second current, if it is carried to a lar
able wires, will maintain the carbon or platinu
state of incandescence. Two or four induction
connected together for lights of the highest powe

PART III.—ELECTRIC LAMPS.

In order to obtain a continuous action from the carbons used for the electric light, these carbons must, in proportion to their consumption, be brought near each other, so that the intensity of the current may be kept as constant as possible. Now in order to obtain this result, arrangements have been contrived which effect it automatically, and these form what are called *regulators* of the electric light, or simply *electric lamps.* Of course the construction of these apparatus varies according as the light is produced by the voltaic arc or by incandescence.

VOLTAIC ARC LAMPS.

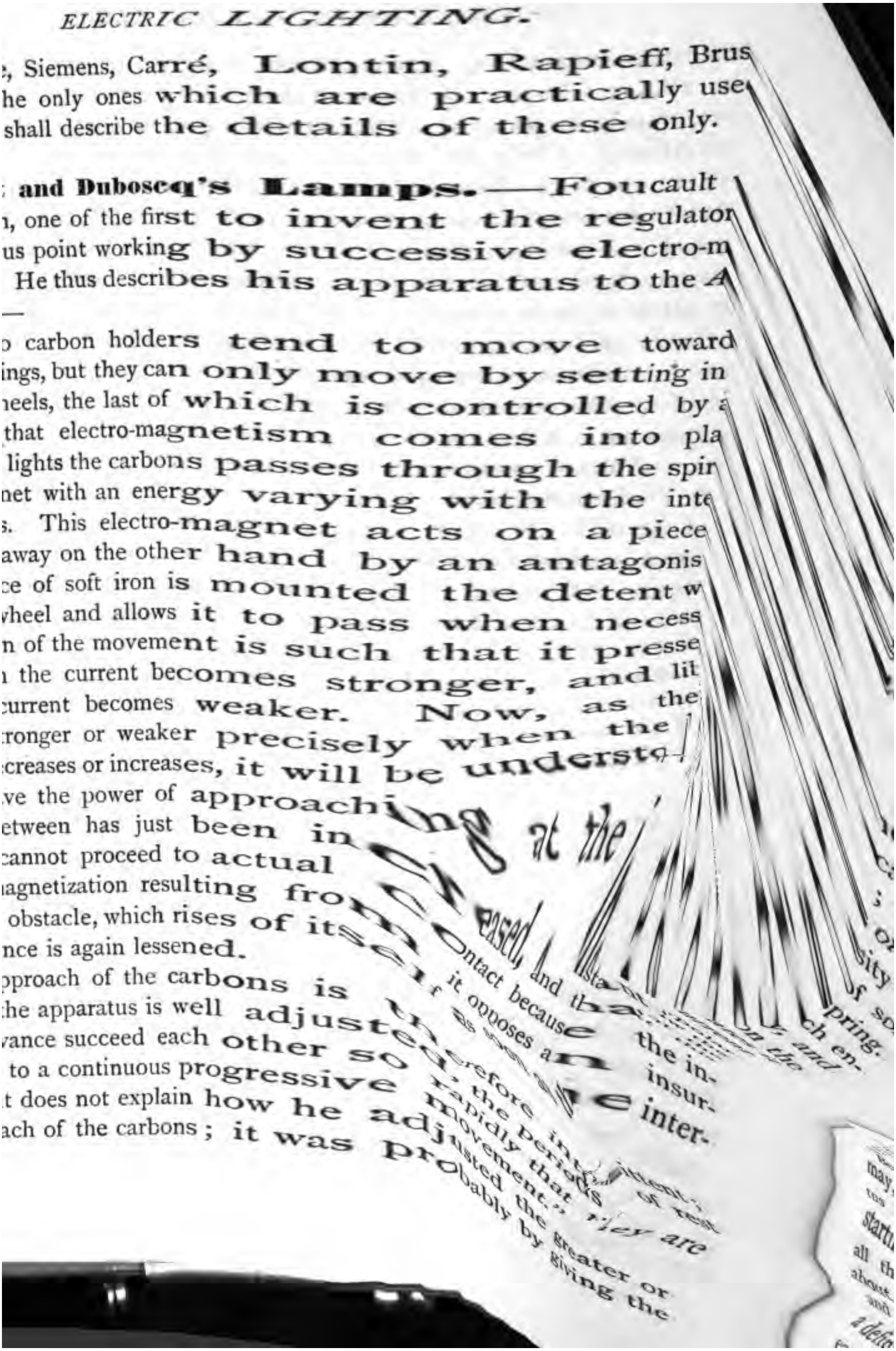
Electric lamps are of an earlier date than is generally supposed. In 1840 they consisted of a kind of Lannes exciter, the balls of which were replaced by sticks of carbon, which were pushed forward by hand as they were consumed, and the apparatus had the form represented in Fig. 1. A little later an attempt was made to render the forward movement of the carbons automatic by placing the holders under the control of clockwork, or of electro-magnetic effects, which could act as a balance, that is to say, on the least variation in the intensity of the current. Then the idea was conceived of arranging the carbons so as to burn like a candle, and it is to this last plan that recourse has been had in the attempts at electric lighting of the streets, which so astonished visitors during the whole period of the Exhibition of 1878.

VOLTAIC ARC LAMPS.

The first automatic electric lamp appears to have vented in 1845 by Thomas Wright; but it was r 1848, when Staite and Petrie, in England, and Fou France, invented their regulators that attention was a to the matter; and before these apparatus could be r as capable of any practical application, Archereau on hand, and J. Duboscq on the other, had used t numerous experiments in projection. From that ti especially after the curious results obtained by the r of the *Alliance* Company, people began everywhere themselves to the improvement of these apparatu multitude of systems were invented, the most importa those of Serrin, Duboscq, Siemens, Carré, Lontin, Brush, &c. Having in the 5th vol. of my *Exposé a cations de l'électricité* described most of these n systems, I shall here concern myself only with th have become common in practice.

Regulators of the electric light may be divided classes, viz.: 1°. regulators founded on the attraction noids, and to this class belong the regulators of Arc Loiseau, Gaiffe, Jaspar, Carré, and Brush; 2°. reg founded on the approximation of the carbons by suc movements produced electro-magnetically, and among we may mention the regulators of Foucault, Du Deleuil, Serrin, Siemens, Girouard, Lontin, Mers Wallace Farmer, Rapieff; 3°. regulators with circular bons, the most important types being the regulator Thomas Wright, Lemolt, Harisson, and Reynier; 4°. r lators with a hydrostatic action, amongst which we may na those of Lacassagne and Thiers, Pascal, Marçais and I boscq, Way, Molera, and Cebrian; 5°. reaction regulato such as those of Fernet, Van Malderen, and Bailhach 6°. electric candles on the Jablochkoff plan, and other The incandescent carbon regulators forming a class by them selves, we shall discuss farther on.

Of all these apparatus, those of Foucault and Dubosc



, Siemens, Carré, Lontin, Rapieff, Brus
he only ones which are practically use
shall describe the details of these only.

and Duboscq's Lamps.—Foucault
, one of the first to invent the regulator
us point working by successive electro-m
He thus describes his apparatus to the A
—

carbon holders tend to move toward
ings, but they can only move by setting in
eels, the last of which is controlled by a
that electro-magnetism comes into pla
lights the carbons passes through the spir
net with an energy varying with the inte
. This electro-magnet acts on a piece
away on the other hand by an antagonis
e of soft iron is mounted the detent w
heel and allows it to pass when necess
n of the movement is such that it presse
the current becomes stronger, and lit
urrent becomes weaker. Now, as the
ronger or weaker precisely when the
creases or increases, it will be understo
ve the power of approaching at the
etween has just been in
cannot proceed to actual
agnetization resulting from
obstacle, which rises of itself
nce is again lessened.
pproach of the carbons is th
he apparatus is well adjusted,
vance succeed each other so
to a continuous progressive
t does not explain how he adj
ach of the carbons ; it was probably

eased, and that
contact because the in-
it opposes an insur-
therefore inter-
the periods of rest
rapidly that they are
movement."
adjusted the greater or
probably by giving the

ch en-
pring.
sity of so

may,
starti
all th
about
and
a defi

pulleys over which passed the cords that moved the carbons an unequal diameter proportional to the amount of the consumption. Nor does he describe the way in which the detent acted; but it seems from his description that it was merely by a simple pressure against a drum fixed on the axle of the two pulleys, on which were wound in opposite directions the cords attached to the carbon-holders.

Be that as it may, this apparatus has been the starting point for all those we are about to mention, and which require a definite place for each pole of the battery.

Some years after the apparatus just

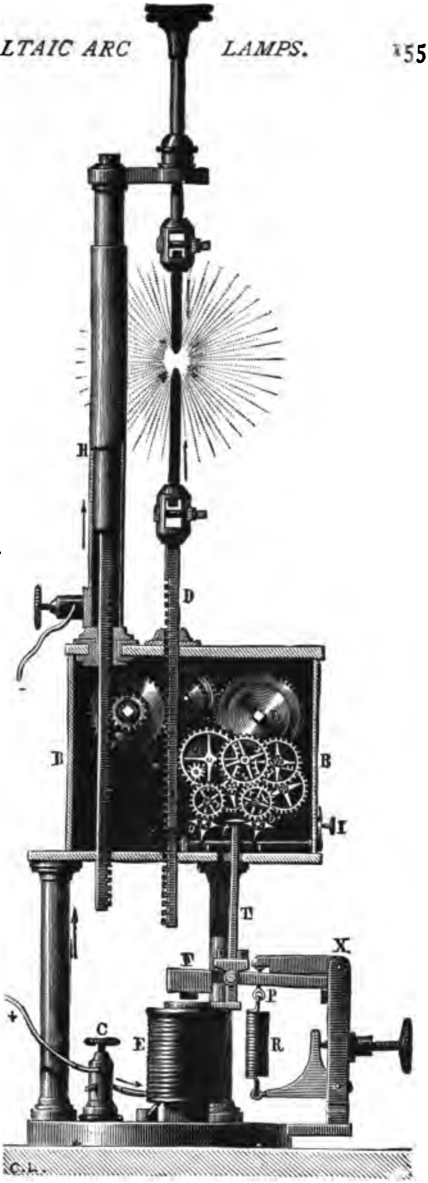


FIG. 38.

described had been invented, and after Duboscq had pointed out the defects he had found in most of the regulators then in use, and even in those he had made himself, Foucault invented a new form which we represent in Fig. 38, and which has been hitherto generally resorted to for all experiments of projection. This is the model which has been constructed by J. Duboscq.

In this new system the carbon-holders B and D end below in racks on which a clockwork movement acts by means of a double wheel, which is arranged in such a manner that the two carbons advance towards each other, and the lower one D moves through twice the distance that the upper one passes through. This arrangement was governed by the unequal consumption of the two carbons, which, as shown on page 20, is double for the positive carbon. To obtain this result, the two racks engage with the two wheels of which we have spoken, and these wheels, fixed on the same axis, have the number of their teeth in the proportion of 2 to 1. To cause this arrangement to act upon the carbons, it is only necessary so to contrive matters that when the intensity of the current becomes a little too feeble an electro-magnet shall act on the clockwork, and that its action shall be stopped when, by the approach of the carbons, the voltaic arc offers less resistance. It is upon this principle that nearly all the regulators of this class have been based; but in order to obtain a perfectly regular action, the problem to be solved was much more complicated, and the special arrangements we have now to study were necessary.

The defect of the regulators founded on the principle we have explained above, was that the electro-magnet armature intended to release or to arrest the clockwork was in a state of unstable equilibrium, and therefore liable to be driven against one or the other of the two stops which limited its play without ever being able to remain in an intermediate position. In order to remedy this, the antagonistic spring R of the electro-magnet E was made, not to act directly on the

armature, but on the extremity P
point x, and having its edge sha
and in rolling pressing on a project
a lever of variable length, as in *R*
tributor. The armature must then
tuating between the two limiting posit
the antagonistic force opposed by the
of the electro-magnet is compensated
lever thus arranged. Or in other words
armature every instant expresses the in
Whilst the intensity preserves its desired
relative to the distance maintained betw
armature is balanced in such a manner
movement of approach or recession; the
becomes too strong or too weak, there
approach, for the lever T attached to the
ture lever F produces these effects by th
escapement anchor *t* fixed at the end of
engages and disengages a double clockwo
action of which we shall now study. In t
and o′ act as detents.

This mechanism represented on a large
is set in motion by two spring barrels
controls its own trainwork of wheels, the la
fly vane mentioned above. The system
barrel L tends to separate, and the ot
together; but in order that these mechanis
site directions may act on the movers of th
mechanical contrivance was necessary, an
course to an arrangement invented by H
of two *sun and planet* wheels *f* and *e*, f
which rotates on the axle *gh*. It is this w
the motion of the double wheel acting on
but it can come into action only when the
nection with the flies o o′ is liberated
netic effect and the movement of the dete

sequence of the liberation of the fly o′, the wheelwork *c d* is allowed to act, the barrel L′ makes the wheel S turn in the direction of the arrow, and the two carbons are brought

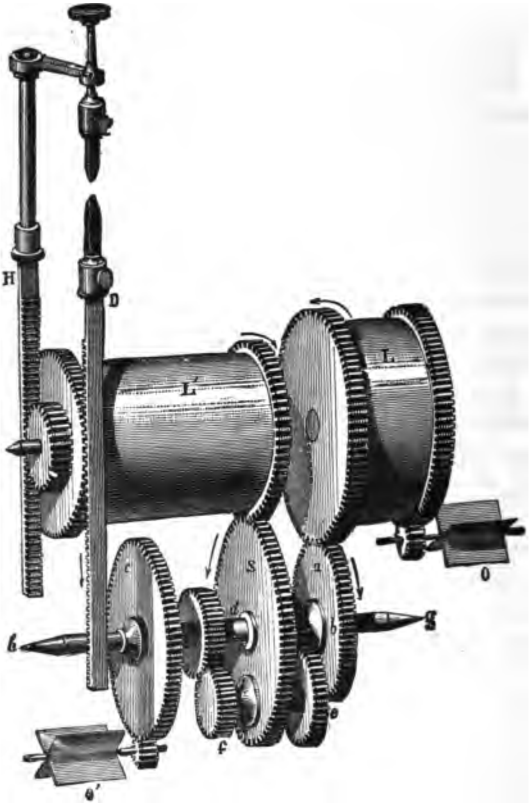


FIG. 39.

nearer together. At the same time, the two sun and planet wheels are turned, but without producing any effect, for they revolve round the wheels *h* and *d;* but when the second fly o is liberated the planet wheel *e* is set in motion by the wheel *a* and the pignon *h*, and by acting through the planet wheel *f* on the wheel *d* it compels the wheel S to move a little in the direction opposite to the former. But to effect this it is necessary that the barrel L should have as much power as L′. In any case the motion can only be very small. The wheels *a* and *b* must be of one piece, but they must move with gentle friction on the axle *gh* in order that the wheel S may turn with making them share its motion. If this much has been understood, it only remains to examine the mode of action of the apparatus.

The arc being established between the two carbons, the attractive action of the electro-magnet is counterbalanced by the antagonistic spring, so that only one of the arms of the escapement anchor engages the fly O′. As the carbons consume, the armature F is the less attracted the more the arc is lengthened, but no sudden movement occurs; the armature drawn away by the spring rolls on the jointed curve X, Fig. 38, and at last the hammer liberates the fly O′, and engages the fly O; the carbons are then approximated until the intensity of the current is sufficient to re-establish the power of the electro-magnet. If the carbons are too near, the armature F is attracted the more, and the escapement anchor will set free the fly O, which will cause a separation of the carbons.

Let us add, that the carbons are capable of being moved in two ways by hand in order to fix the position of the luminous point in the first instance. Thus, the upper carbon may be moved independently of the lower one, the whole system may be raised or lowered, the separation of the carbons continuing unchanged; and this is required for properly centring the light in projections.

An important improvement has lately been made in this apparatus. It had been found that changes in the intensity of the current modified the condition of the magnetic core, and that the magnetic power persisted more or less. The antagonistic spring regulated by a screw, seen on the right in Fig. 38, was therefore unable for a given electric intensity to maintain the equilibrium, and if too great a tension were given to it the movement of the apparatus became too jerky.

This inconvenience has been got rid of by so arranging the armature, to which a curved form is given, as to vary its distance from the poles of the electro-magnet. This motion is produced by the friction of an eccentric lever. This slight modification is shown in Fig. 40, which represents the external appearance of the apparatus. As the least variation sensibly alters the effective power of the attraction, the action of the electricity may then be easily and very exactly regulated, according to the power of the electrical generator at a given instant.

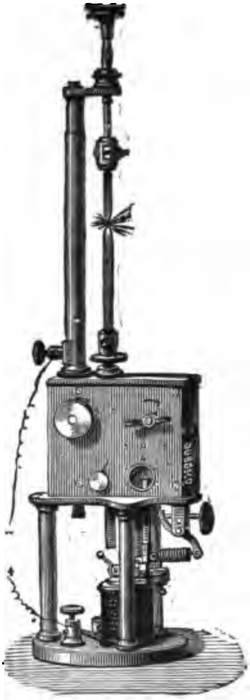


FIG. 40.

In this new model the positive pole may be placed above or below as required. The + pole should correspond with the upper carbon for lighting purposes, and with the lower carbon for optical experiments, such as the combustion of metals, &c.

"This new regulator," says Duboscq, "fulfils all the conditions required for the application of the electric light to scientific experiments, and to the illumination of lighthouses, vessels, workshops, theatres, &c.

"In the present state of science the electric light is as commonly produced with the magneto-electric machine as with the battery; it may even be affirmed that the *industrial generator* of the electric light is magnetic action: witness the electric lighting of lighthouses, ships, yards, &c. It was therefore requisite to make the regulator suitable for these two sources of electricity. When the arc that springs between the carbons is derived from the battery, they are consumed in the ratio of 1 to 2; if, on the other hand, it is derived from the magneto-electric machine, the consumption of both carbons is alike, since the currents are alternating. In the former case it is necessary to arrange the advance of the carbons in the ratio of 1 to 2, and in the latter to make it equal. An addition to the mechanism enables the change of the relative velocities of the carbons to be made in an instant, according as one or the other source of electricity is made use of.

"Thus improved, the new regulator is perfectly adapted to all the applications of the electric light."

Serrin's Lamp.—Of all the regulators yet invented, that of Serrin is the one most used when a prolonged illumination is required. We have had the pleasure of following the various phases through which this apparatus has passed since its invention, and we were the first to give a complete account of it in *tome IV.* of the second edition of our *Exposé des applications de l'électricité*, published in 1859. At a later period, Pouillet, in a report made to the *Académie des Sciences*, explained its ingenious arrangements. Finally, the experiments made with the machines of the *Alliance* Company showed that it was then the only apparatus that could work with currents alternately reversed. Since that period this regulator has been constantly used in the various experiments that have been made with the electric light, and it is the one adopted in the illumination of lighthouses. We must therefore dwell a little on this ingenious apparatus, which is so sensitive that an india-rubber ring placed between the two carbons is sufficient to arrest their progress without the ring losing its shape.

This apparatus, which is able, like that of Duboscq, to keep the luminous point stationary, is essentially formed of two mechanisms mutually connected, but each producing its own effect on the movement of the carbons. One of these mechanisms, in direct communication with the electro-magnetic system, forms an *oscillating system*, composed of a kind of double jointed parallelogram, to which are attached the tube and accessories belonging to the lower carbon. It is formed of four parallel horizontal arms, turning on the tube of the upper carbon-holder and connected together by two vertical cross pieces.

The other mechanism, which we shall call *the advancing mechanism*, is connected with the carbon-holders, and is formed of wheelwork, together with a rack and draw chain. The first mechanism, while acting, as we shall see, directly on the lower carbon-holder, controls the action of the second mechanism; and this last, by rendering regular the approach of the carbons towards each other, carries out the mechanical effect begun by the first. With this object, the tube belonging to the lower carbon and forming part of the oscillating system, carries a stop of triangular shape which acts on the wings of a fly, forming the last moving piece of the advancing mechanism. The oscillating system connected by the two vertical cross pieces carries a cylindrical armature, which being placed within the influence of an electro-magnet acting tangentially on it, can more or less lower it according to the intensity of the current traversing the system. There are two opposing springs fixed to the lower arms of the oscillating system, and these springs are attached to the supports of the wheels, and raise the system when the current does not act with energy sufficient to counteract their effect. It follows therefore from this arrangement that, with an adequate electrical intensity, the oscillating system is sufficiently lowered to arrest the advancing system, and with an inadequate intensity this last system, being set at liberty, allows the carbons to approach each other merely by the effect of gravity on the upper carbon-holder, which is heavy enough to produce the movement of the system. Let us now see how the advancing system is arranged.

In the first place, it is formed of a set of four wheels, the first of which engages a rack, making part of the upper carbon-holder, and has its axle provided with a drum, round which is wound a Vaucanson chain; this chain, after having passed over a pulley, is attached to a piece connected with the lower carbon-holder. It follows that when the oscillating system, in consequence of the inactivity of the electro-magnet, has liberated the wheel, the upper carbon-holder is free to descend, and in descending not only causes all the wheels to turn, but also raises, by means of the Vaucanson chain, the lower carbon-holder. This action goes on until the current, by becoming stronger, produces a more powerful action on the electro-magnet, which thereupon engages, by means of the oscillating system, the fly in the train of wheels. The apparatus is then stopped until the energy of the electro-magnet again diminishes. A second opposing spring, acted on by an adjusting screw, allows the sensitiveness of the instrument to be increased or diminished at pleasure. Lastly, a chain hanging down is so arranged as to act as a counterpoise to compensate, in the action of the oscillating system, for the loss of weight occasioned by the consumption of the lower carbon.

The current is transmitted to the lower carbon through a bent flexible plate which follows the carbon in its movements, and it is transmitted to the upper carbon through the mass of the apparatus and the electro-magnet which has the free extremity of its coil connected with an external binding screw.

There is nothing special about the lower carbon-holder: it is merely a socket provided with a pressure screw for holding the carbon; but the upper carbon-holder is more complicated, in order that it may have two rectangular movements so as exactly to fix the two carbons in the desired relative position. The positive carbon is maintained above the negative by means of a tube, supported by two horizontal jointed arms controlled by two screws. One of the screws allows the carbon-holder to be displaced in one vertical plane, and the other, by means of an eccentric, displaces the carbon in the vertical plane perpendicular to the former.

Serrin has made several patterns of his regulator to suit the greater or less electric intensities that are to act upon it. His largest pattern is arranged to burn carbons of 15 millimetres broad, or 225 square millimetres in section; and, in spite of these large dimensions, it is as sensitive as the smallest patterns. In the pattern made for lighthouses, the inventor has made several important modifications. Thus, by means of a little arrangement adapted to the chains of the carbon-holders, he has been able to shift the luminous point to a certain extent without putting out the light. This is very important in the application of these apparatus to lighthouses, for it gives the means of correctly centring the light with regard to the lenses.

Again, as these regulators have to act with extremely powerful currents, the heat in the circuit would be sufficient to burn the insulating covering of the coil in the electro-magnet, and thus destroy its effect. Serrin has made the electro-magnetic spirals with metallic helices unprovided with insulating covering, and so arranged that the spires cannot touch each other. In order that these helices might be adapted to the magnetic cores and to the discs of the electro-magnet with a sufficient insulation, he has covered these cores with a somewhat thick layer of vitreous enamel, as well as the inner parts of the discs; and in order to obtain as many spires as possible with the maximum of section, he has cut these helices from a copper cylinder of a thickness equal to that of the coils. In this way the electro-magnetic helices are represented by a kind of close screw thread of a projection equal to that of the discs, and having its central part represented by the magnetic cores and the covering of enamel.

It will easily be understood that with this arrangement the helices may be carried to a very high temperature without the spires ceasing to be insulated from each other, for they are not in contact, and they are separated from the body of the electro-magnet by a substance which cannot be changed by the most elevated temperature. Besides, the large section of the spires thus formed makes the heating more difficult than with ordinary arrangements, and that is not one of the least advantages of this kind of electro-magnet.

I ought, in justice, to state that previously to Serrin an electro-magnet of this kind had been invented by Duboscq for his regulator, but he had not taken care to enamel the parts in contact with the helices, considering that precaution as useless, on account of the great section of the spires of the helix, which prevented them from being raised to redness. Nor did he form his spires in the same way: they were simply a strip of copper hammered into a spiral.

Siemens' Lamp.—The last of Siemens' lamps, which is much used in England and in Germany, is represented in Fig. 41. Like that of Serrin, it can be lighted automatically, and the two opposite actions required for the separation and approach of the carbons are determined by the weight of the upper carbon-holder and by the electro-magnetic vibration of a rocking lever which acts on a clockwork mechanism driven in the opposite direction by the weight of the carbon-holder. This mechanism, composed of four wheels, is arranged nearly as in the regulators we have just described, and it is on the last wheel I, furnished with a ratchet and a fly with wings, that the vibrating electro-magnetic acts. This last is formed of a bent lever L, jointed at Y, and carrying at M the armature of the electro-magnet E. This is the principal organ of the apparatus, for on one side it carries a contact piece which forms with the stud X the vibrating circuit-breaker, and in the second place the antagonistic spring of the system, the tension of which is regulated by means of the screw R, and finally the driving and stopping catch Q, which acts on the clockwork mechanism by means of the ratchet wheel I. A fixed piece S supports the end of this catch, in order to liberate the wheel I, at a suitable inclination of the lever L. Finally, a screw K, which passes through the case of the lamp, allows the distance of the armature to be properly adjusted to the current employed, and a small addition N, which also projects from the case, shows whether the electro-magnetic system is properly vibrating. The wire of the electro-magnet E is moreover connected with the mass of the apparatus, in order that the current which passes through and illuminates the carbons may be derived through the circuit-breaker at each attractive movement of the armature, and produce the vibration of the lever L by closing a short circuit.

The action of this apparatus is very simple. When a current passes through the electro-magnet E, the catch Q is withdrawn from the wheel I, and the upper carbon-holder, by weighing on the wheels of the clockwork, sets them going until the carbons guided by racks engaging these wheels are brought into contact. But if under these conditions the generator is put into communication with the lamp by the binding screws Z and C, the current traverses the electro-magnet E, the mass of the apparatus, the upper carbon-holder, the lower carbon-holder, and returns to the generator by the communication connecting this with the binding screw Z; the carbons then glow at their point of contact, the electro-magnet becomes active, and the catch Q, by acting on the ratchet wheel I, causes it to advance one tooth, by which the carbons are separated. But in this movement a contact is set up at X between the lever and the screw C, and the current, finding less resistance in passing by that path than through the electro-magnet E, in a great measure leaves the latter; then the armature, being no longer sufficiently attracted, causes a backward movement of the lever L, which again withdraws the catch Q, destroys the contact at X, and brings about a new attraction of the armature involving a new movement of the wheel I; and as these alternating motions are more rapidly effected than that which results from the setting in motion of the wheels by the action of the upper carbon-holder's weight, the carbons are soon sufficiently apart to produce a voltaic arc of suitable size, which increases in length in consequence of the consumption of the carbons; but when their distance apart becomes too great, the intensity of the current becoming too weak is unable to cause the attraction necessary for the action on the wheel I, and then the wheels can turn freely, causing thereby the approach of the carbons, which goes on until the current has regained an intensity sufficient to again produce the effects we have already studied. By a suitable adjustment of the screws R, K, and Z, the double inverse action we have just examined may be made very regular. But this adjustment is very delicate, and that is perhaps an inconvenience of the system.

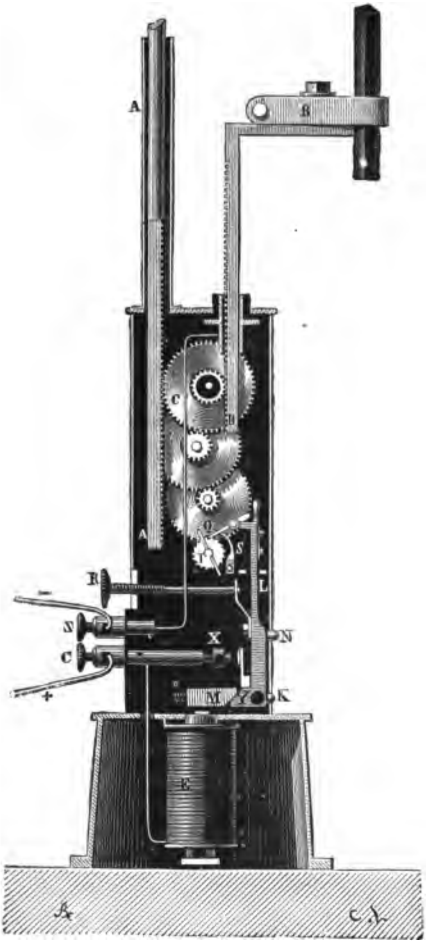


FIG. 41.

The apparatus is moreover provided with two other systems of regulating screws, one of which moves the two carbons and the luminous point without extinguishing it, and the other allows one of the carbons to be displaced. Finally, screws attached to the upper carbon-holder give a means of easily fixing the carbons with regard to each other so as to supply a diffused or a condensed light. Two small bull's-eyes in the side of the lamp allow the action of the delicate parts of the mechanism to be observed, and the effects of the regulator to be noted.

In order that the generator of light may work always under the same conditions, whatever may be the variations in the circuit external to the lamp, Siemens has interposed in the circuit a regulator of resistance which we are going to describe, as it has more importance than at first sight would be supposed; for these variations, by changing the conditions of velocity in the motor, on one hand, and on the other by causing many sparks, may injure the machine and the collector. By 1856 Lacassagne and Thiers saw the necessity of a regulator of this kind, and had invented one which I have described in my *Exposé des applications de l'électricité, t. V., p.* 506, and which was an accessory of their electric lamp; but these systems had been little used before Siemens.

Siemens' arrangement consists of an electro-magnet with a thick wire, the armature of which acts in the manner of a relay on a contact which, when the armature is not attracted, has the effect of introducing into the circuit a derivation with a resistance nearly equal to that of the voltaic arc. With a suitable regulation of the antagonistic spring, the derivation is therefore substituted for the voltaic arc whenever the resistance of the latter becomes so great that the armature is no longer retained. This is what happens not only when the lamp is put out or withdrawn from the circuit, but also when very great variations occur in the working of the lamp. The helix forming the derivation is placed in a tin vessel filled with water to prevent the wire from becoming too hot during long interruptions of the current, such as those required by replacing the carbons.

The lamp just described is not, however, the only one made by Siemens. He has already patented eight forms.

Lontin's Lamp.—From a published account of the Lontin machines we extract the following description of this lamp:—

"The first and principal advantage of this regulator is that its moving and regulating parts are such that it can work in any position, upright, horizontal, or upside-down, and without being stopped or changed in its action by even the strongest shocks or oscillations.

"In these regulators a quite new application has been made of the heating produced by the current in a metallic wire to cause the separation of the carbons and keep it perfectly constant. Thus the use of electro-magnets is dispensed with, and the consequent cost of the additional electric power required to overcome their resistance in the circuit, while the length of the arc remains absolutely fixed, so that a more regular light may be obtained.

"The approach of the carbons in proportion to the combustion is obtained by another not less happy application of a derived current taken from the light current itself, and acting as follows:—

"There is a solenoid in the apparatus formed of a coil of fine wire in quantity sufficient to offer a very great resistance to the current. This coil encloses a movable iron rod, which when at rest keeps back the moving power that brings the carbons nearer together. So long as the carbons are at a distance adjusted to the amount required for a good light, the whole current passes through them, on account of the great resistance of the coil; but when the separation increases, a small portion of the current passes through the coil and excites it so that the movable iron rod is attractive, and the moving power released from its stop brings the carbons nearer by the amount required for maintaining the length of the arc; at this moment the solenoid ceases to act, and the irod rod again stops the motor, which has merely to bring the carbons nearer together and is extremely simple."

This employment of a derivation from the light current may also be advantageously applied to all the regulators which automatically separate the carbons, and it renders their action more certain and regular, whatever may be the variations in the intensity of the current. This system has been successfully applied to the Serrin regulators, used at the *Chemin de fer de l'Ouest* (*St. Lazare* station).

De Mersanne's Lamp.—De Mersanne's regulator was invented to enable straight carbons to supply an electric light for at least sixteen hours consecutively.

The system, represented in Fig. 42, is essentially formed of two slide boxes B B′, fixed on a strong upright stand of cast iron. Through these slide the two cylindrical carbons C and C′, each 75 centimetres or more in length, móved by a regulated action. In order that the carbons may be adjusted to have their points in the same vertical line, the boxes are capable of turning a little vertically, and the upper one can also be turned horizontally. The sliding system of both boxes consists of four grooved rollers, two of which are connected with the two ends of a lever, and are pressed against the carbons by a spiral spring *v*. These rollers serve as guides, and the other two, of larger diameter and with a roughened surface, act as the movers of the carbons. For this purpose these are set in motion by wheels fixed on an axle, connected by mitre wheels with a vertical shaft A A. This shaft, being capable of turning in either direction, according to the action of the regulating apparatus, can make the carbons approach to, or recede from, each other. The carbons are supported and protected outside of the boxes by enclosing tubes.

The regulating apparatus is placed in a case below the slide box B′ of the lower carbon. It consists in the first place of clockwork driven by a spring barrel,* and by an electro-magnet E forming part of a derived circuit from the two carbons, as in Lontin's system; and in the second place, of another electro-magnet M interposed in the same derivation, and acting on the box B′ of the lower carbon in such a manner as to separate the carbons when they come into contact. When the apparatus is not in action, the carbons are generally separated by a greater or less interval; but as soon as the circuit is closed through the apparatus, the two electro-magnets are excited, for the current then wholly passes through the derivation, and the clockwork is liberated, while the lower holder is so inclined as exactly to bring the two carbons one over the other. The advance of the carbons takes place slowly, and when they come into contact, the current, finding a more direct path, abandons the derivation and the electro-magnets, and passes almost entirely through the circuit of the carbons, which then glow, and immediately supply the voltaic arc. The electro-magnet M having become inactive, the box B′ of the lower carbon-holder is slightly inclined forward, and by this causes not only the disjunction of the carbons, but also a sufficient separation of their points in consequence of the action produced on the

---

* This barrel, when wound up, will act for 36 hours without attention.

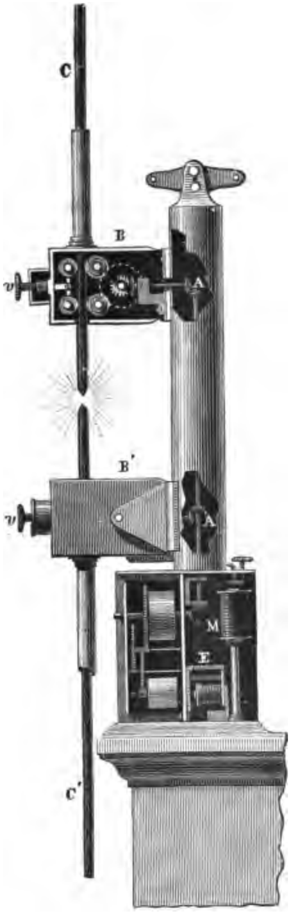


FIG. 42.

wheels by the movement of the box. The lamp is thus lighted; but in proportion to the consumption of the carbons, the resistance of the light circuit increases, and the current, passing with more intensity into the derivation, soon becomes sufficiently powerful to release the clockwork that brings the carbons together, until the current has regained its full intensity in the light circuit. Things go on in this way until the carbons are entirely consumed.

It will easily be understood that with this arrangement there is no limit to the length of the carbons, since it may exceed that of the apparatus, and without their requiring any particular position. Their forward movement takes place as if they glided between the fingers of two hands, pushed towards each other by two thumbs guiding their progress.

This lamp, like those of Serrin and Siemens, may be lighted from a distance, which is not one of the least of its advantages. A medal was awarded to it at the *Exposition Universelle* of 1878.

Bürgin's Lamp.—This lamp is already rather old, and we are surprised that it has not been described anywhere, for, according to what Soret has communicated to me, it works in the most satisfactory manner. It was shown at the *Exposition* of 1878, but, its inventor being absent when the jury went round, it was not examined. It is used continuously at Geneva for the theatre and for the illumination of a public clock.

Bürgin has made two patterns of this lamp, one of which is for industrial purposes, and is represented in Fig. 43; the other, more complicated, is intended for scientific experiments. The principle of the lamp is very simple: the two carbon-holders tend to approach each other continuously by the influence of a spring barrel or a counterpoise; but they can obey this tendency only when a check controlled by an electro-magnetic action permits the passage of the chain or chains which support the carbon-holders, so that, according as the current is more or less energetic, there is motion or rest in these carbon-holders. In the pattern shown in Fig. 43, this result is obtained by means of a large wheel R, which carries on its axle the pulley C, on which is wound the chain supporting the lower carbon-holder. The axle of the wheel rests on a piece of iron A A fixed to a jointed parallelogram, and serving as the armature of an electro-magnet E connected with the light circuit. A spring break F presses on the circumference of this wheel, and is sufficiently bent to prevent the wheel from turning when the latter is at the proper height, that is to say, when the armature A is at its greatest approximation to the electro-magnet E; but when, in consequence of the weakening of the current, this armature is at a greater distance, the wheel, by dropping with the armature, withdraws from the break and is then able to turn by the effect of the weight of the lower carbon (or of a spring barrel attached to this carbon-holder), acting through the chain which is wound about the pulley C. Thereupon the lower carbon-holder rises, and the current, resuming its

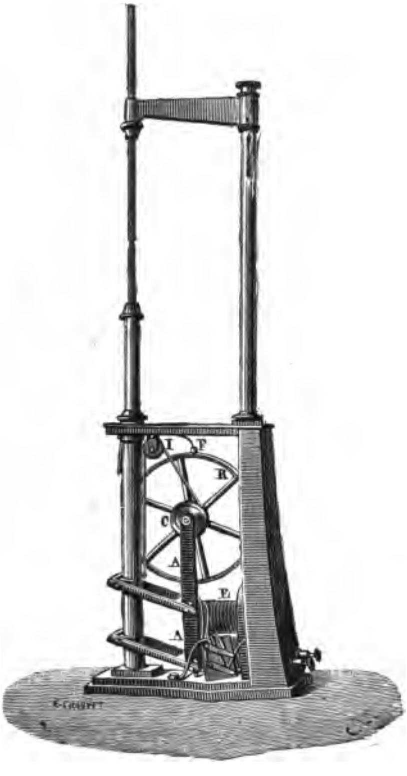


FIG. 43.

energy, quickly produces a fresh engagement of the wheel, which checks the rise of the carbon at the proper instant. The slight movement of the attracted armature A, when the carbons are in contact, suffices to allow the passage of enough chain to bring about the separation of the carbons when the circuit is closed.

In this pattern the upper carbon is fixed, and therefore the luminous point changes its position, a thing of no consequence for ordinary illumination; but for experiments of projection, the two carbons must be so arranged as to move simultaneously in the proportion of 2 to 1, and for this purpose Bürgin fixes the two carbon-holders to two chains, which are wound upon two pulleys of unequal diameter, mounted on the axis of the large regulating wheel, so that each movement of that wheel causes a double displacement of the carbons. An adjusting screw attached to the break allows the apparatus to be made more or less sensitive. In this pattern it is the weight of the upper carbon-holder which, as in Serrin's regulator, brings the carbons together, and the attractive action of the electro-magnet first determines their separation in order that an arc may be formed, and afterwards stops them so as to maintain their due interpolar distance.

Gaiffe's Lamp.—In 1850, Archereau, reflecting upon the considerable space that a rod of soft iron will move within a coil under the influence of the magnetic attractions, invented a regulator based upon that principle. He formed one of the carbon-holders of a rod, half of copper and half of iron, placed within a long coil, and to properly balance the attractive force he used a counterpoise. This was, therefore, one of the simplest of regulators, and it had the advantage of being capable of lighting at a distance. In the hands of skilful experimenters, it could work well, but the movements being too abrupt and the oscillation too large, it often went out, and was not in fact a practical lamp. Jaspar and Loiseau succeeded in lessening these defects, but it was not

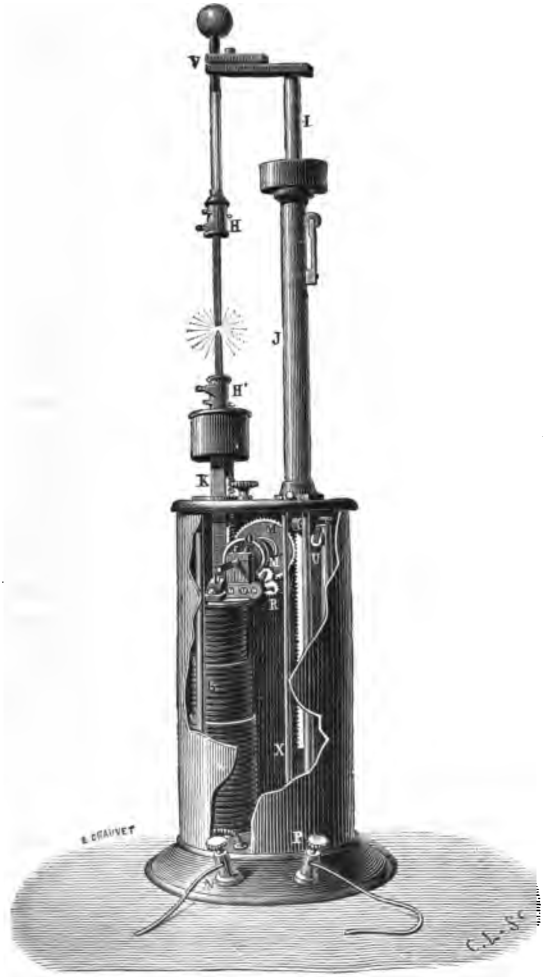


FIG. 44.

until Gaiffe invented the regulators represented in Fig. 44 that the advantage of this plan became obvious.

In Gaiffe's Lamp the two carbon-holders H, H′ are movable, as in Foucault's and in Serrin's arrangements, and they are so arranged as to keep the luminous point stationary. For this purpose their motion is controlled by two racks K, U, which engage two wheels M′, O, of unequal diameter, and moved by a simple spring barrel on the axle of which they are fixed. This barrel is wound up by the mere separation of the carbon-holders, which are, however, perfectly balanced and turn between sets of rollers. The lower carbon-holder is terminated by an iron rod K, to which is attached a rack, and this rod is placed within an electro-magnetic bobbin L, with a coil increasing in diameter from its upper to its middle part in order to compensate for the unequal action of the spring barrel through the whole range of this movement. Finally, a small wheel R connected by the wheels M′, O, and another to the wheel M gives the means of simultaneously acting on the two racks so as to raise or lower the luminous point.

In the normal state the carbons touch each other, and when the current traversing them excites the coil, the lower carbon-holder is lowered at the same time that the upper one HVI is raised, and this effect is continued until the attractive force of the coil balances the resistance of the spring barrel, and thus a voltaic arc is produced. Of course the length of the arc depends upon the tension of the spring in the barrel, and this can be regulated by a screw. So long as the arc remains under the same conditions of resistance, the effect is maintained; but the moment the resistance increases on account of the consumption of the carbons, the power of the spring prevails over the electro-magnetic action, and the carbons are brought nearer together, until a condition of equilibrium is again attained, and the same thing goes on until the carbons are entirely consumed.

The small mechanism fitted to the wheels of the racks allows the luminous point to be raised or lowered, by means of a key, without the lamp going out, and this is necessary in optical experiments in order to properly centre the light.

Carre's Lamp.—Carré's Lamp, which received a g medal at the *Exposition of 1878*, and is represented in 45, is only an ingenious improvement on Archereau's and Gaiffe's regulators. As in those, the electro-magnetic action is founded on the attractive effects of solenoids, but these effects are by an ingenious arrangement very much magnified, and the mechanical action is produced, as in the regulators of Serrin, Foucault, &c., by clockwork acting on two racks D, E, fixed to the carbon-holders, and controlled by a detent brought in action by the electro-magnetic system.

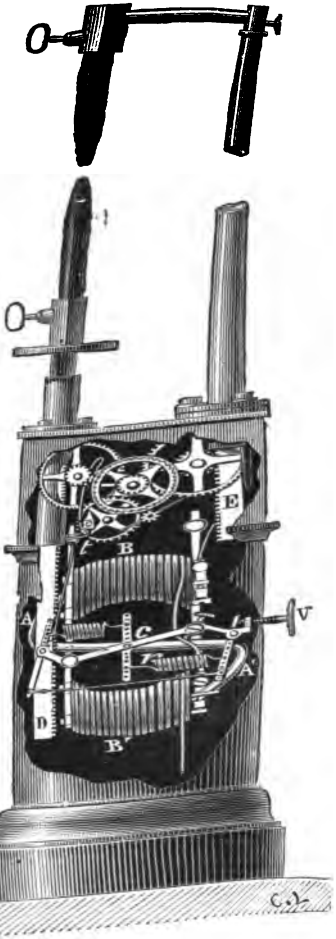


FIG. 45.

This system is formed of two coils B, B', having their axes slightly curved, and into these pass the ends of a soft iron core A A bent into an S shape, and turning at its middle part about the centre C. A double set of antagonistic springs *r*, *r'*, regulated by a system depending upon the adjusting screw V, allows the force opposing the attraction of the coils to be suitably adjusted, and t fixed to the magnetic core acts on the detent of the ork. The motion of the wheels causes a forward nent of the two racks in the proper proportion for ng the point of light stationary. The light current s through the two coils, and according as its intensity eater or less, the iron core is more or less attracted n the coils, a sufficient enfeeblement causing a release e detent, whereupon the approach of the carbons ensues. this system, as in those of Archereau, Gaiffe, Jaspar, eau, &c., the increase of the current has the effect of rating the carbons from each other, and the clockwork gs them nearer together; but as under these conditions path of the movable piece in the electro-magnetic system onsiderable, and as the attractive effect is much less den than in the case of electro-magnets with turning atures, the separations of the carbons are produced freely d without oscillations, which is an advantage.*

These are the regulators which, during the whole duration the *Exposition*, have worked with the machines of the *liance* Company. With alternately reversed currents, they er real advantages, for J. Van Malderen has shown that th these currents an iron rod is almost as strongly drawn o a coil as with direct currents, only there is a much eater heating of the electro-magnetic system; but to com- nsate for this there is much less residual magnetism, and refore greater sensitiveness.

rush's Lamp.—The report of the American Commis- appointed to examine magneto-electric machines having wed great praise on this lamp, we have considered it uty to give a description of it here, although it appears nferior to those we have in France.

lamp, which is represented in Fig. 46, is, like the pre- based on the attraction of solenoids. The electro-

---

he laws of the attractions of solenoids in *tome II.* of my *Exposé des ons de l'électricité*, p. 132.

magnetic coil is at A, above the upper carbon-holder, and is supported by the arm *b* fixed to a vertical piece *c* sliding within a column so as to adapt the apparatus to different lengths of carbons. Inside of the coil a magnetic core *d* moves freely. This core is hollow, and through it passes the copper rod *ff* of the upper carbon-holder, sliding freely for its whole length. A sort of collar *h* grasps it, however, a little below the magnetic core, and is so arranged that when it presses on a cross piece *h*, forming part of the fixed system of the arm *b*, it leaves the rod *ff* free, which then descends by its own weight. The collar therefore maintains the rod only when it is itself raised up, and this takes place almost constantly during the working of the apparatus, for a catch *e* fixed on the magnetic core supports it above; but in its rise it cannot go beyond a certain limit which can be adjusted, for a screw has a head large enough to hold it by its upper edge.

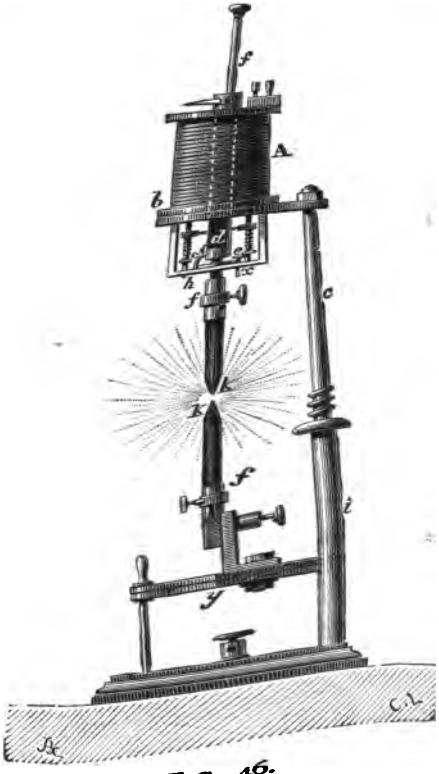


FIG. 46.

The magnetic core itself is kept up by a cross piece o which act two spiral springs, the rods of which serve a the same time as guides. The carbon-holders have n particular feature; one is fixed to rod *ff*, the other to a ted to the supporting column, and this last is arranged a manner as to be capable of moving when the con- on of the carbon requires; for in this system it is only urse of the upper carbon that is regulated electro- tically, as in Archereau's original regulator. We must at the coil A is formed of two helices which may, by of a commutator shown at the top of the coil, be ed either for tension or for quantity, according to the ions of the experiment.

action of this apparatus will be readily understood: is not working, the two carbons *k k* are in contact, current can pass through them when the carbon- are connected with the electric generator. Under ence of the current, then at its maximum intensity, netic core *d* is raised up, carrying with it, by its catch, lar *h*; the rod *ff* is then raised, and the two carbons ted; the voltaic arc is produced, and, so long as the action is kept within proper limits, the apparatus re- in the condition brought about by the rise of the ; but when the consumption of the carbons becomes ently great to notably weaken the current, the core *d* down again, and with it the iron rod *ff* and the *h*. If this descent is not complete, the carbons ap- ch each other only by the distance the core has dropped; should it be so great that the collar *h* presses on the ss piece *h*, the rod *ff* is liberated and falls by its own eight until the approach of the carbons is sufficiently great o bring about a fresh ascent of the core *h*.

Jaspar's Lamp.—Jaspar, of Liége, was one of the first to turn his attention to electric lamps, and in the second edition of our *Exposé des applications de l'électricité*, published in 1856, we have described the first system he sent to the *Exposition* of 1855. Since that time he has paid little attention to the subject, and it was not until the *Exposition* of 1878 that he again entered the lists with other inventors of lamps and obtained a gold medal. This honour compels to give some details of this new apparatus, which, it appear acts remarkably well.

The apparatus is, like the preceding, based upon the attraction of solenoids acting directly on the carbon-holders by means of chains passing over pulleys of unequal diameter, and this action can be regulated by a counterpoise which acts on the antagonistic force. But the improvement in the original apparatus consists in this: the lower carbon acts on a rod with a piston which moves freely in a tube filled with mercury, and produces two useful effects. In the first place, it prevents any abrupt movement of the carbon-holders, for the mercury being able to pass but slowly through the narrow space between the piston and the interior surface of the tube, resists a too rapid rise or descent; in the second place, it affords an excellent contact for the negative rod.

The small counterpoise serving as antagonistic force has also a happy arrangement. It slides on a small rod jointed horizontally, with one end connected with the free extremity of the chain of the lower carbon-holder; so that, by moving backward or forward an externally projecting stud, its effect may be increased or diminished.

Experiments made with this lamp have proved very satisfactory. It is now applied at Sautter and Lemonnier's, in the workshops of Cockerill and Seraing, in Denayer's paper manufactory at Willebroek, at the *Gare du Midi* at Brussels, &c.

Rapieff's Lamp.—This system is only an extension of Bailhache's, in which the carbons are kept always at the same relative distance in spite of their consumption, by means of a spring pressing on them like the candle springs of carriage lamps. In Bailhache's system the carbons were kept at a distance suitable for the formation of the arc, by two hollow cones of calcined magnesia in which their points were placed, and which formed a kind of stop-collar. As ties burned away, they were pushed forward by and as they became thin by burning at the ex- y, the cold part always remained within the re- ne. In Rapieff's system the same effect is pro- there are no refractory cones, these being replaced cks of carbon joined at the ends two by two at an e, and so arranged one above the other as to form ar systems in planes perpendicular to each other. ts of contact which form the electrodes are sepa- from the other by the distance desired for forming arc. Counterpoises with pulleys are arranged to carbons of each system one against the other, and ese carbons are consumed, they constantly advance he common point of intersection, which remains the same place.

represents this regulating system, the carbons of *b b′*, seem to form an X, with this difference, that wer carbons are placed in a plane perpendicular which the upper ones are placed. The voltaic arc at c, between the upper and the lower pairs of the carbons are consumed, they slowly move ch other in each couple, under the influence of ise w, which, through the cords and the pulleys *e g d′ b′ b*, pushes the sticks of carbon against This counterpoise is guided in its course by s s′, which at the same time serve as conductors ing the current to the two systems of electrodes ported also by the two metallic arms *d h*, *d′ g*. carbons are to be connected with the positive of course longer than the lower. This arrange- leted by an electro-magnetic system enclosed in e apparatus; and its office is, when the current four sticks of carbon are in contact, to sepa- systems to the distance necessary for the for- arc. This effect is produced by means of a to the electro-magnetic armature, which cord,

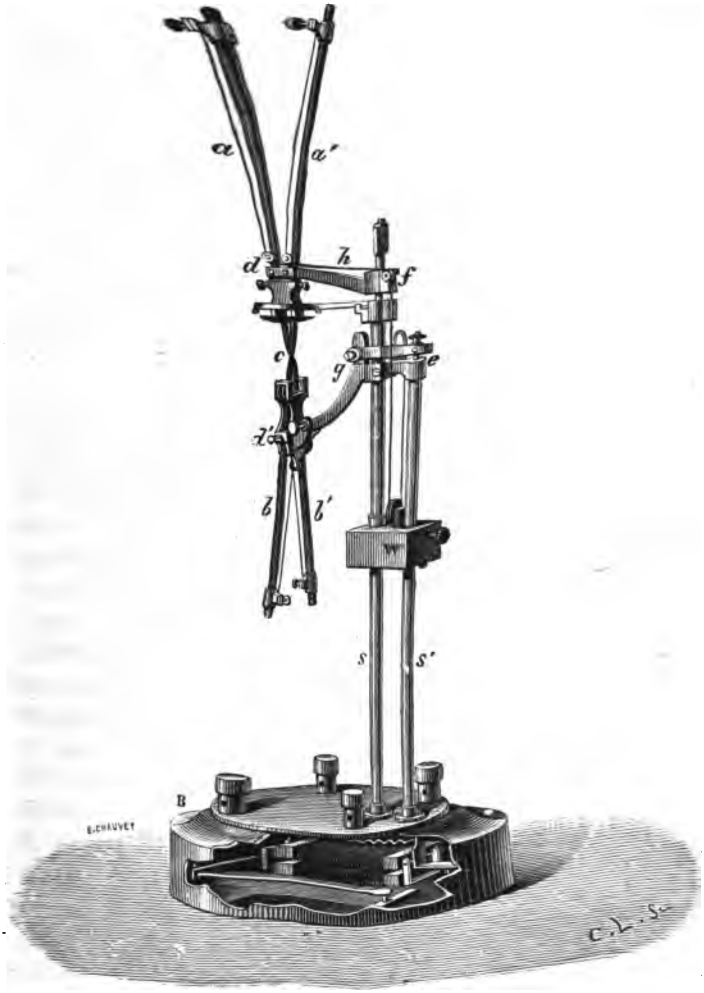


FIG. 47.

passing within the column s, acts on the arm *d′ g*. A reflector of a cup shape, either of silvered copper or of porcelain, is fixed a little above the point of contact of the carbons, djusting screws enable the luminous beam to be turned y required direction.

th carbons 20 inches long and 5 millimetres in diameter, ight supplied by the lamp lasts, according to Rapieff, ven or eight hours; but with a diameter of 6 millimetres carbons may last two hours longer. This light may be oned at 100 or 120 gas-jets, or at 1,000 candles; but Rapieff's smaller patterns one may be obtained not exceeding 5 gas-jets. The inventor has also constructed rns in which the preceding arrangement is reversed, in r that they may be hung from the ceiling. According m, the resistance of the arc does not exceed 3 ohms, or metres.

another arrangement Rapieff combines the action of oltaic arc with the luminous effect of a piece of kaolin ed above the arc. The four carbons are then arranged to form the four edges of a pyramid broken off at its mit, where a kind of bell of kaolin is placed, like the guisher of a lamp, and this when glowing increases the inating power, according to Rapieff, by 40 per cent. carbons are Carré's, and a Gramme machine is the rator. With this machine 10 lamps of the first described ern may be lighted by placing them in the same circuit, only 6 are used in the *Times* office at London, where mode of lighting has been in use for some time.

According to the *Telegraphic Journal* of the 1st November, 1878, Rapieff's system of electric lighting, introduced to England by E. J. Reed, under the direction of Applegarth, has given excellent results in the trials which have been made at Smithfield and at the establishment of the London *Times*. The compositors' room is now lighted by 18 Rapieff lamps, and 6 are appropriated to lighting the offices. "The great advantage of this lamp," he says, "is that it will go a whole night without a renewal of the carbons; its intensity is always constant, even when the carbons are burned very low, and in this respect the lamp is preferable to the Jablochkoff candle, for in this the current increases in energy as the candle burns on account of the decrease in the length of carbon the current has to traverse, whilst in the Rapieff lamp that length is always the same.

In order that the extinction of one lamp may not cause that of other lamps, Rapieff arranges the electro-magnet that separates the carbons in such a manner that it acts as a commutator. When the current passes through the electro-magnet, the commutator is not brought into action, and the circuit is completed through the lamp; but when this is extinguished or withdrawn from the circuit, the electro-magnet in question becoming inactive causes the current to pass through a derivation on which a resistance equal to that of the lamp circuit is introduced, and the circuit of the other lamps is not interrupted thereby. This effect is obtained by means of a second armature, which, being attracted when the current passes, acts as a keeper, thus increasing the electro-magnetic action exercised on the lamp, and sets the commutator in action, when the current no longer passing, the armature yields to the antagonistic action.

In a new pattern, Rapieff has replaced the upper carbons of the regulator we have described by a large piece of carbon, which, as in Werdermann's lamp, does not burn. This arrangement had, however, been indicated by Rapieff in his patent of 1877, so that he cannot be accused of having imitated Werdermann in his new arrangement. It is this form that is now most employed.

Baro's Lamp.—This apparatus is composed simply of two metallic tubes placed vertically one beside the other, and in these slide freely two sticks of carbon, which rest on a block of magnesia. These tubes are separated by an insulating substance, but a screw regulates the distance between the carbons at the end in contact with the magnesia, so that the arc may be produced at this point of contact under the desired conditions, and be kept there in spite of the con-the carbons, for these continually tend to ap- lock of magnesia by their own weight. A lamp had previously been invented by Staite.

Farmer's Lamp.—This system is so primitive surprised that it has received any attention. It with a view to obtaining a longer duration of and with this object thin plates of carbon are of carbon pencils. These plates are placed so very small angle with each other, so that the arc essively displaced as the carbons are hollowed ctro-magnetic mechanism analagous to those of s brings the plates nearer together as the action this mechanism acts by variations in the intensity of the current. It is certain that a lamp on this system lighted for a long time; but we very much doubt electric intensity it produces can be compared other lamps, for the incandescent part of the then considerably reduced in extent and calorific

ston and Thomson's Lamp.—As regards arrangement Houston and Thomson's Lamp resembles the ordinary tus; only the lower carbon, instead of being connected clockwork mechanism, is supported by an arm fixed strong flat spring. This arm carries the armature of an tro-magnet placed below it, and is insulated metallically m the upper carbon-holder, which is placed in communication with the positive pole of the electric generator. The electro-magnet is in metallic communication with the lower carbon and the negative pole of the generator, so that the circuit is completed through the elastic arm of the lower carbon-holder and the two carbons. The electro-magnetic armature forms therefore a trembler, as in an electric bell, and the effect is a very rapid series of interruptions of the current between the two carbons; and this occasions repeated sparks, and thence a continuous light by their superposition on the organ of sight. In order to avoid a continuance of the action on the carbon-holders when the carbons are consumed, the upper carbon-holder has a head, which by meeting a circuit-breaker stops the current through the apparatus. Under these conditions, the spark of the extra current of the electro-magnetic system is joined to that of the generator, and increases its brilliancy.

Houston and Thomson do not, of course, announce this regulator as suitable for feeble currents and lights. Maiche sought the same object, and Lemolt also used this means to produce a voltaic arc with powerful generators, only it was a clockwork mechanism which gave the vibrating movements to the carbons.

Molera and Cebrian's Lamp.—This system of lamp was invented for distributing the light in several directions by optical means. The apparatus consists, therefore, of a regulator, with the luminous point enclosed in a polyhedric cage, with faces provided with Fresnel's lenses. With this object, the two carbons are supported by two systems of regulating carbon-holders entering at a certain angle within the cage, and directed towards its centre. These carbon-holders are fitted to the two ends of a tube filled with a liquid, in which they form a kind of pistons which may be pushed to a greater or less distance according to the pressure exercised by the liquid in the tube. At one part of this tube there is a kind of bellows, the movable part of which is provided with a plate of iron, which serves as the armature of an electro-magnet placed in the arc circuit. This armature being more or less energetically attracted, according to the greater or less intensity of the light current, exercises a greater or less pressure which causes the carbons to advance proportionally to their consumption, and therefore maintains them in the centre of the cage. This pressure may, however, be regulated by means of an antagonistic screw. When current is interrupted or weakened, the spring acts so as to bring the carbons nearer together; when, on the contrary, increases, the inverse effect is produced and the carbons are separated. Lacassagne and Thiers had, as will be presently seen, used a system of the same kind.

On each face of the polyhedron, formed by the reflexion [illegible] about tubes which are arranged so as to carry the rays collected by the lenses in certain directions; and according to the *Scientific American*, these tubes may be placed in the streets, along buildings, or even under the floors, in order to distribute the light in a house. For that purpose it would suffice to fix a stout branch pipe with a properly inclined mirror at each change of direction.

By means of this system, says the American journal, each street in a town may be provided with one or more pipes carrying a certain quantity of light, which may always be governed by simply changing the position of the reflectors. The problem may thus be reduced to the conditions of a water supply.

Without stopping to discuss these rather fantastic dreams of American inventors, we think we ought to give here some figures they have published relative to the system of lamp we have described. According to these, 195 lamps on this system can be supplied by 1-horse power, and a light obtained equivalent to 1,958 candles, for which it follows that this illumination would cost only one-twentieth the price of gas. It is needless to say that we cannot accept such figures, and if we give them, it is only to show to what length the prolific imaginations of Americans will go. (See the *Telegraphic Journal* of 15th July, 1879, p. 231.)

Lamps of various kinds.—In order to complete our monograph of the voltaic arc lamp, it remains only to speak of various plans which, although they have not given very important results in practice, nevertheless have an originality of character which deserves attention. Of this number is

Girouard's lamp, which is a clockwork regulator somewhat resembling that of Foucault or Serrin, but acting under the power of a kind of relay-regulator, and therefore capable of being controlled from a distance. The system consists, therefore, of two apparatus: 1°. An electro-magnetic coil with thick wire, through which the current of the generator passes, and which acts on a double contact; 2°. A lamp with a double clockwork motion, on which act two electro-magnets with fine wires, excited by the current of a battery of very feeble intensity. The current of the generator, after having traversed the electro-magnet of the relay-regulator, passes directly, therefore, through the carbons of the lamp, and their distance apart is regulated by an independent system which works by the influence of the two contacts of the relay-regulator. When the current has its full intensity, the mechanism controlling the separation of the carbons is set in motion, and when on the contrary the current is too much enfeebled, the second clockwork mechanism is liberated, and this brings the carbons nearer together. In order to obtain this double action in opposite directions, Girouard used a spring barrel with a double movement. The complete description of this system may be found in vol. V. of my *Exposé des applications de l'électricité*, p. 495.

In order to increase the duration of the carbons, circular carbons have been used. Indeed, the first electric lamp was made by Thomas Wright on this system. Subsequently, in 1849, Lemolt, taking up Wright's idea, constructed a better apparatus, in which the two discs of carbon, supported by two curved and jointed levers, were set in motion by a double system of pulleys driven by the clockwork mechanism. A spiral spring connecting the two curved levers, pressed the two carbon discs against each other, and these were separated at very short intervals by the action of an eccentric put in motion by clockwork. The result was a series of sparks succeeding each other rapidly enough to impress the sight as a continuous light. After this system came that of in which one of the carbons was replaced by a linder, movable on its axis, so as to make the con- slower. The upper carbon was moved by an agnetic system, which determined the formation of the arc and kept it constant by means analagous to those employed in other regulators.

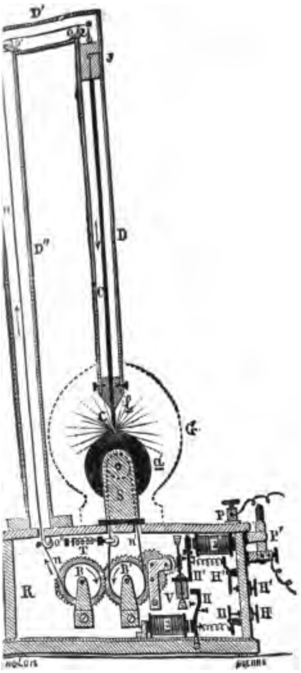


FIG. 48.

Ducretet has improved this lamp by arranging it so as to give simultaneously with the arc powerful incandescent effects. Fig. 48 represents this new arrangement, which, I am told, has given very good results.

Lastly came Reynier's system, the most complete of all, in which each of the carbon discs was set in motion separately by a special clockwork mechanism, and the separation necessary for the production of the arc was obtained by an tro-magnetic system acting on one of the carbon-holders, producing effects like those in the other regulators of kind. (See my *Exposé, t. V., p.* 502.)

esides the apparatus of which we have just spoken, there ts a class of electric lamps to which, in my work on the lications of electricity, I have given the name of regu- rs with hydrostatic actions, and which are at least very resting, though not very practical. For the regulating organs, they have liquids which act either by communicating vessels, or by serving as the medium of discharge under certain conditions, or by producing an effect like that of the moderator lamps. The principal forms in this class are those of Lacassagne and Thiers, Pascal of Lyons, Marçais and Duboscq, and Way.

In Lacassagne and Thiers' apparatus, invented in 1856, only the lower carbon is movable, and it is directed by a float fitted in a long cylinder filled with mercury, which is placed in communication, by a tube, with a reservoir of the same liquid, and this last is fixed on the column that supports the upper carbon-holder. The tube that establishes the communication between the two vessels is bent across one of the poles of a powerful electro-magnet so as to present its curvature beneath the armature, and from this arrangement it results that the armature, pressing on the part of the tube when the current has its whole intensity, plays the part of a stopper. So long, therefore, as the current keeps all its power, the level remains the same in the two vessels, and the lower carbon continues motionless; but when the current becomes feeble by the increase of the length of the arc, the tube is then liberated a little, and a small quantity of the liquid passes from the reservoir into the tube, and this causes the carbon to rise until the current, having resumed its original intensity, has again occasioned the obstruction of the tube. The action of the spring antagonistic to the electro-magnet is regulated by a second electro-magnet placed in a very resisting derivation of the circuit, and which acts in the same direction as it would on the armature of the large electro-magnet, which is for this purpose prolonged beyond its pivot.

Marçais and Duboscq's regulator is a kind of moderator lamp, the rack of which acts on the two carbon-holders by means of a double pinion, and in which the movement of the piston depends on the more or less rapid flow of the oil below it. For this purpose, the upper and lower parts of the body of the lamp are connected by a tube, at one part of which is a circular opening stopped by an extensible membrane, and above this membrane a kind of plug is applied controlled by the armature of an electro-magnet, which, as in the foregoing system, stops or allows the flow of the liquid according to the greater or less intensity of the current.

In Way's lamp, which was much talked about in 1856, and which moreover caused its inventor's death, the carbons between which the voltaic arc is generally produced were replaced by a fine stream of mercury issuing from a small funnel and received into an iron basin also containing mercury. The two poles of the generator being connected, one with the funnel and the other with the basin, a series of voltaic arcs were produced between the successive drops of the discontinuous stream, and the combination of these arcs formed a source of light tolerably brilliant and uniform. The luminous vein was enclosed by a glass tube sufficiently narrow to become so hot that the mercury should not condense on its surface; and as the action took place out of contact with oxygen, the mercury was not oxidized. Way modified this first arrangement by using two jets of mercury instead of a single one, and these jets were so arranged that they met together at one point, from which they flowed on in drops. He also closed and interrupted the currents continually by means of a small electro-motor set in motion by the battery, and which drove the mercury pump that supplied the jets. But in spite of these improvements, it was necessary to abandon this apparatus on account of the mercurial vapours that escaped from it, and which at length killed the inventor. 56 Moreover, the light attained to little more than a third of that produced by the same current between two carbon points.

As a special form of arc lamp, I must say a few words about J. Van Malderen's regulator, which is based upon the repulsions between the contiguous elements of one and the same current. It is a kind of suspended compass, the jointed arms of which carry at their ends the carbon-holders, which are therefore horizontally opposite to each other. These two arms of the compass are insulated from each other and are very readily movable. They are connected with the two branches of the circuit, and when the carbons come into contact by the tendency of the carbon-holders to place themselves vertically, the passage of the current which then takes place produces a repulsion that separates the carbons and produces the arc. There is then established a state of equilibrium between this repulsive force and that due to gravity. This state of equilibrium is sufficiently stable to render the arc comparatively steady. But this system can be used only with currents of small intensity, and it cannot be considered of any practical use. The same may be said of that of Fernet, which is arranged according to the same principle.

In conclusion, we shall mention a lamp invented by Dubos, which is rather interesting from its arrangement.

In this lamp the luminous point remains fixed without any clockwork, in consequence of the shape of the two carbons, which are semicircular. These carbons are supported by two arms jointed to a pivot in the centre of the circumference formed by the two carbons. As in the ordinary regulators, an electro-magnetic mechanism fixed to the carbon-holders brings them together as they are consumed. As these displacements take place circularly, the point of contact of the two remains always at the same height, and consequently the same is the case with the luminous point.

There are yet a few other lamps which were shown at the Exhibition at the Albert Hall, and which have been described in various works, in those of Fontaine and Higs, among the rest; but these lamps are merely more or less complicated modifications of those we have described, and therefore we shall here merely make a note of them. Of these, we shall passable. A relative of Truc, the Paris lampmaker, at whose house Kosloff's experiments were made, also worked at this lamp with much enthusiasm without effecting any material improvements; and it was not until Konn had invented his lamp in 1875 that it was possible to enter upon experiments which held out any promise of practical advantages from lamps of this kind. It was Duboscq who first made this lamp in France.

Konn's Lamp.—In this apparatus, which is represented in Fig. 50, each luminous centre, instead of having only one carbon, was provided with four or five, and all these carbons A B, arranged vertically and circularly, were terminated by small carbon cylinders in which were incorporated, in the upper parts, rods of copper A B of a successively decreasing length. Their lower part was connected with one of the branches of the circuit, but the upper part was connected with the other branch only by means of a kind of jointed metallic cap which rested on them by its own weight. Their height, however, being different, this cap could only touch the longer one. Now, it would follow from this arrangement that if this last were to break or be completely consumed, the cap would fall on to the next longer one, and would thus send the current through a fresh carbon, which would be instantly illuminated. The latter again breaking, the cap would transmit the current into a third carbon, and so on until the last. Experience had shown that five carbons thus arranged were ample for an evening's illumination, and during some experiments at which I was present I have twice seen the lamp working at the moment of the rupture taking place.

Each of these quintuple systems of carbons was of course enclosed in a hermetically sealed vessel w, from which the air had been exhausted, and their difference of height was calculated so that the curvature produced by the great heat should not cause a division of the current.

When all the carbons of one lamp were consu
cap, by meeting with a copper rod, continued the ci

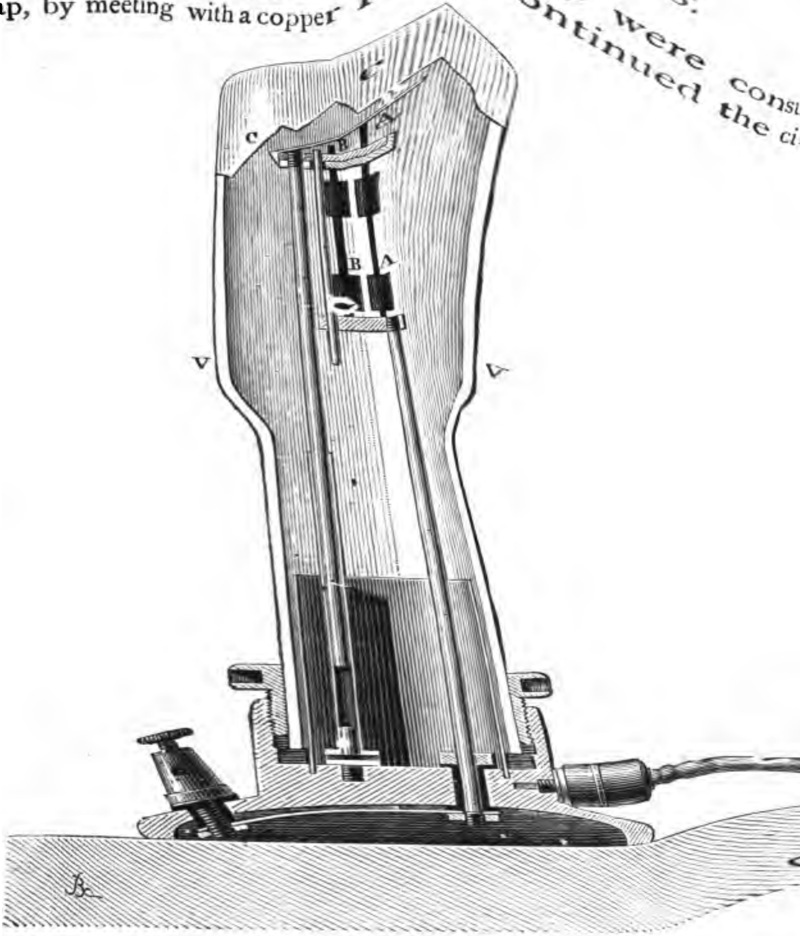


FIG. 50.

that, if there were several lamps included in the sa
the extinction of one of them did not involve that of
According to the experiments made at Flore

rsburg, where three of these lamps are in operation, each em gives a light equal to 20 Carcel lamps, and they are ced by the currents of one of the *Alliance* Company's chines.

Bouliguine's Lamp.—This lamp accomplishes nearly e same object as the preceding, but by using only one caron. It is, like the former, composed of a copper base, two ertical rods, two bars for conveying the current, and a valve for exhausting.

One of the rods is perforated by a small opening from top to bottom, and nearly all its length there is a slit which allows two small lateral projections to pass through. The carbon is introduced into this rod as into a porte-crayon, and it tends to rise, by the action of counterpoises attached by very small cords, to the lateral projectors on which the carbon rests. The part of the carbon to be made incandescent is held between the lips of two conical blocks of retort carbon. A screw placed under the base enables the length of the rod which carries the upper conical block to be increased or diminished, and thus a greater or less length can be given to the luminous part. The closing of the globe is accomplished, as in the preceding apparatus, by the lateral pressure of several caoutchouc discs.

When the lamp is placed in a circuit, the carbon rod glows and becomes luminous, until at length it breaks. At this instant a little mechanism controlled by an electro-nagnet opens the lips of the carbon-holders; the counteroise of the upper one pushes out of the groove any fragents which may remain, and the counterpoise of the lower e raises the carbon rod, which goes into the upper block l re-establishes the current. The mechanism controlled he electro-magnet again acts, but in the reverse direction ts former movement, the porte-crayons are tightened, the light reappears.

is system, according to Fontaine, does not always yield good results, on account of the multiplicity of its parts when by chance it does work regularly, the light it giv more intense than that of the Konn lamp.

Sawyer-Man's Lamp.—This lamp is nothing more King's or Lodyguine's in all its simplicity, except son significant arrangements for lessening the calorific radi and we are surprised at the long accounts we read i English journals about this lamp, which is probabl better than the older ones. In this system, the vesse taining the incandescent carbon is filled with nitro avoid combustion and the deposition of volatile produ the surface of the vessel. The carbon itself is rather its resistance does not exceed 0·95 ohm, and each supplied with a derivation, in order that the conditions distribution of the current may not be changed when of the lamps is extinguished. The commutator used f ing and extinguishing the lamp is, moreover, arranged a manner that the current gains its full intensity degrees, and after having passed through successivel resistances. It is, according to Sawyer-Man, from n this precaution that the carbons of incandescent la so soon spoiled. Finally, an electro-magnetic regis cluded in the circuit, and has the same effect as a g

We shall not speak of the system of distributing th among all these lamps, for it is founded on the pr derivation, and is identical with that of Werderman we shall presently consider. A detailed descripti lamp may, however, be seen in the *Telegraphic Jou* January, 1879. We think it unnecessary to say m it, than to express our surprise that English and inventors trouble themselves so little about the ventions.

E. Reynier's Lamp.—We have seen, on pag principle on which this lamp is based. The lamp i important of all those that we are now examining; it perhaps may some day, under one form or other, solve the problem

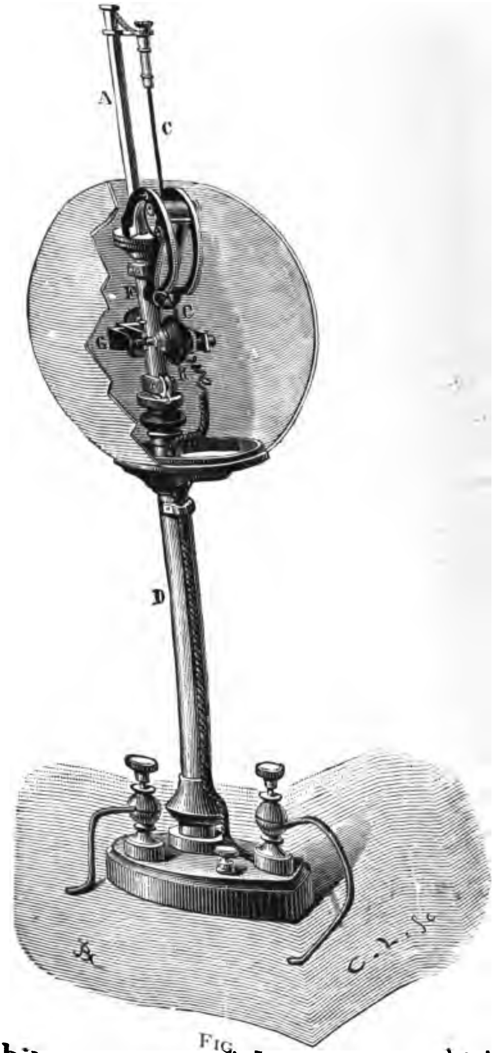


FIG. 51.

of the divisibility of the electric light. The best known form of it is represented in Fig. 51. It is composed, as will be seen, of a long and slender rod of carbon C 2 m in diameter, supported on a heavy carbon-holder slides on a hollow column D between four rollers. rests on a cylinder of carbon R, turning on a horizo c fixed to the column. A guide, fitted with a bra closes the rod of carbon to a short distance (6 mi about) from the carbon cylinder, and at the same t ducts to it the positive current, which returns to t rator by the carbon cylinder and its support. A brake F, placed behind the apparatus and resting support A of the movable carbon through an opening in the tube D, moderates the action of the weight support A, according to the degree of pressure exer carbon disc R. For this purpose, the support of the this disc forms a rocker, and on the side of the rocker op the disc R is fixed the second brake, of which we are spea

The point of contact of the rod of carbon with the cyl is placed a little eccentrically, in relation to the vertical ing through the axis of the cylinder, so that at each lowe of the system from the consumption of the rod, a small gential impulse may be given to the cylinder, which ca it to make a slight movement that suffices to throw down ash accumulated at the point of contact. Without this caution, this ash might interfere with the brilliancy of light, at least with the impure carbons which are at pre in use.

The problem which Reynier undertook to solve was may be seen, to make a long slender rod of carbon in descent towards its extremity, and while wasting at the to be moved forward continuously and regularly. Fig taken from the French patent of the 19th February, clearly explains the data of this problem.

"A cylindrical or prismatic rod of carbon C," says Rey "is traversed between *i* and *j* by a continuous or alter e lateral contact has a less complicated arrangement, and e weight P which acts on the movable carbon to produce he end contact, is placed above the upper end of the carbon. t may therefore be selected as required. The end contact tself is fixed instead of turning round. The arrangement given to the apparatus enables it to be suspended from a ceiling. It can also be placed horizontally: in that case a spring propels the movable carbon.

---

* See *le compte rendu des séances de la Société de Physique* for July, 1878, p 96.

Experiments made at Sautter and Lemonnier's, with ten Reynier lamps and a Gramme machine with a speed of 930 turns, gave the following results in a circuit represented by 100 metres of copper wire of 3 millemetres, or 30 metres of telegraph wire:

Number of lamps in tension.	Indications of the galvanometre.	Luminous intensity of each lamp.	Total yield of light.
5	25°	15 jets	75 jets.
6	22°	13 —	78 —
7	20°	10 —	70 —
10	15°	5 —	50 —

Serrin's regulator gave under the same circumstances, with a deviation of 21°, a luminous intensity of 320 jets.

As regards total luminous intensity, the use of incandescence lamps is therefore less advantageous than that of arc lamps; but with the former there is the advantage of the division of the light, and the possibility of obtaining it with comparatively small electrical power. They consume about 10 centimetres of carbon per hour; but by taking larger carbons and arranging the generators for quantity, this consumption may be much reduced. In the experiments made at the *Société d'encouragement*, six lamps could be lighted with the current from 25 double Bunsen cells. Their light through ground glass globes was soft, and appeared about equal to that of two or three gas-jets. They could be lighted and extinguished at will.

In the year 1876, S. A. Varley had patented a lamp on a similar plan which we show in Fig. 55, and which is described as follows:—

"A rod of carbon T rests gently by its weight and that its carrier on the periphery of a roller of retort carbon and the *imperfect* contact thus produced gives rise to incandescence and combustion of the stick of carbon at extremity."

We may remark, however, that with this arrangement which the transmission of the current to the movable carbon is not produced by a sliding contact, placed at a short distance from the point, that the light is only produced at the point of contact, and it can be but very feeble, whilst with Reynier's system, in which this sliding contact exists, the portion of the carbon between it and the roller is heated to incandescence. *It appears also, on an attentive examination of the patent, that the carbon roller* N *was made of alter* sulating and conducting portions; and as it was su *to a rapid rotatory movement, the light was the res series of sparks which were produced at the mome passage of the carbon* T *on each of the insulating*

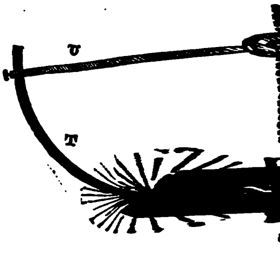


FIG. 55.

Werdermann's Lamp.—Werdermann's lamp is ciple merely Reynier's lamp reversed; but this arra is more practical for public illumination, for whic specially intended, and it makes use of the vol action. It is represented in Fig. 56.

This system consists essentially of a slender c moving within a metallic tube T, which serves at guide and conductor of the current. A collar fixed lower part connects it—by means of two cords whi the tubes by two grooves and pass over two pulleys counterpoise P that tends constantly to raise the car to keep it lightly pressed against a large carbon dis inches diameter, which is kept in a fixed position by a vertical support D. This support is fixed to a kind of funnel-shaped covering S, which receives the ashes from the combustion, and permits a glass globe to be fitted to the lamp.

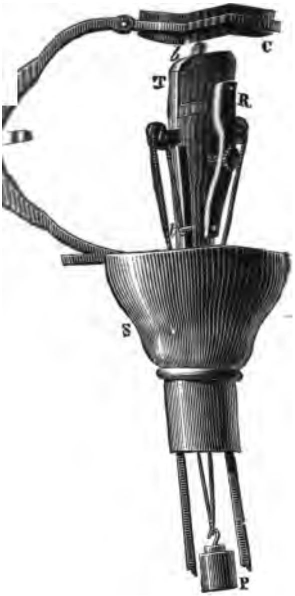


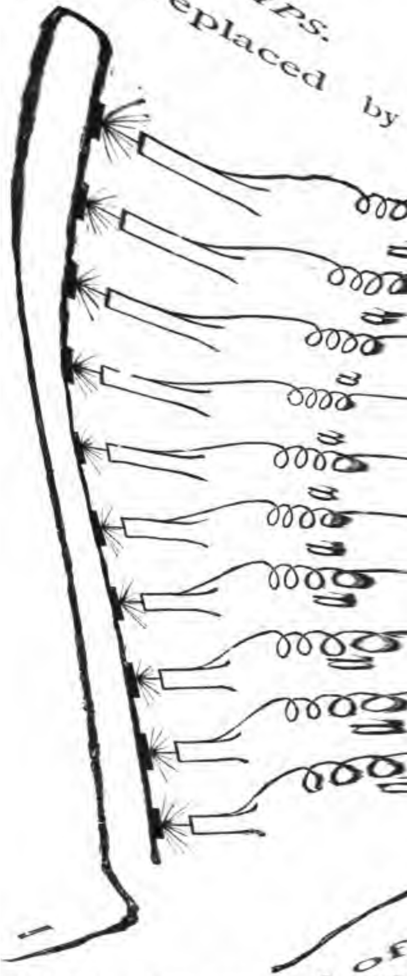
FIG. 56.

The upper carbon disc is connected with the negative pole f the generator, and the metallic guide T of the carbon pencil corresponds with the positive pole, so that only the portion of the carbon between the tube and the upper carbon is brought to incandescence. This incandescence is increased by the action of the small voltaic arc which, as we have said, is formed at the point of contact of the two carbons, and it is increased also by the combustion of the attenuated carbon. The upper carbon, by virtue of its greater mass, neither burns nor changes. The action of the counterpoise is regulated by means of a spring R provided with an adjusting screw, which, by pressing more or less on the part of the tube surrounding the carbon, acts as a brake. The greater or less pressure of this brake depends on the formation of the voltaic arc between the two carbons, or merely on the incandescent effects, and it is in this circumstance that the difference between Werdermann's and Reynier's system specially resides. In the latter the movable carbon is too contracted to take part in the formation of an arc, whilst in the other this carbon is sufficiently free for this effect to be produced; and thus the diameter of the movable carbon may without inconvenience be increased for the purpose of making it last longer. In he new forms of the Werdermann lamp the upper disc of carbon has been advantageously replaced by copper.

Experiments made in England with a Gramme machine arranged for electroplating and worked by a steam engine of (it is stated) two horse-power,* gave, according to Werdermann, the following results:—

"1°. When the current of the machine was distributed between two lamps, the brightness of the light was equal to that of 360 candles. This light was white, and apparently free from the blue and red ray so often perceived in the light of the voltaic arc. It was, besides, perfectly steady.

"2°. By placing in the circuit 10 derivations, each corresponding with one lamp, as shown in Fig. 57, 10 luminous centres could be obtained, each representing about 40 candles. In order to render the action steady, coils *a a a* of small resistance are interposed in each derivation. Under these conditions the resistance of



was 0·392 ohm, and therefore the total resistance o

was only 0·037 ohm.

---

* According to the particulars sent to me, this power shoul

Petersburg, where three of these lamps are in operation, each of them gives a light equal to 20 Carcel lamps, and they are worked by the currents of one of the *Alliance* Company's machines.

Bouliguine's Lamp.—This lamp accomplishes nearly the same object as the preceding, but by using only one carbon. It is, like the former, composed of a copper base, two vertical rods, two bars for conveying the current, and a valve for exhausting.

One of the rods is perforated by a small opening from top to bottom, and nearly all its length there is a slit which allows two small lateral projections to pass through. The carbon is introduced into this rod as into a porte-crayon, and it tends to rise, by the action of counterpoises attached by very small cords, to the lateral projectors on which the carbon rests. The part of the carbon to be made incandescent is held between the lips of two conical blocks of retort carbon. A screw placed under the base enables the length of the rod which carries the upper conical block to be increased or diminished, and thus a greater or less length can be given to the luminous part. The closing of the globe is accomplished, as in the preceding apparatus, by the lateral pressure of several caoutchouc discs.

When the lamp is placed in a circuit, the carbon rod glows and becomes luminous, until at length it breaks. At this instant a little mechanism controlled by an electro-magnet opens the lips of the carbon-holders; the counterpoise of the upper one pushes out of the groove any fragments which may remain, and the counterpoise of the lower one raises the carbon rod, which goes into the upper block and re-establishes the current. The mechanism controlled by the electro-magnet again acts, but in the reverse direction of its former movement, the porte-crayons are tightened, and the light reappears.

This system, according to Fontaine, does not always yield good results, on account of the multiplic when by chance it does work regularly, more intense than that of the Konn lamp.

Sawyer-Man's Lamp.—This lamp is King's or Lodyguine's in all its simplicity significant arrangements for lessening the c and we are surprised at the long accounts English journals about this lamp, which better than the older ones. In this system, taining the incandescent carbon is filled wi avoid combustion and the deposition of volati the surface of the vessel. The carbon itself is its resistance does not exceed 0·95 ohm, and supplied with a derivation, in order that the con distribution of the current may not be changed of the lamps is extinguished. The commutator ing and extinguishing the lamp is, moreover, arra a manner that the current gains its full inte degrees, and after having passed through succes resistances. It is, according to Sawyer-Man, fr this precaution that the carbons of incandesce so soon spoiled. Finally, an electro-magnetic cluded in the circuit, and has the same effect

We shall not speak of the system of distribut among all these lamps, for it is founded on derivation, and is identical with that of Wer we shall presently consider. A detailed de lamp may, however, be seen in the *Telegrap* January, 1879. We think it unnecessary t it, than to express our surprise that Engl inventors trouble themselves so little ab ventions.

E. Reynier's Lamp.—We have seen principle on which this lamp is based. T important of all those that we are now examining; it perhaps may some day, under one form or other, solve the problem

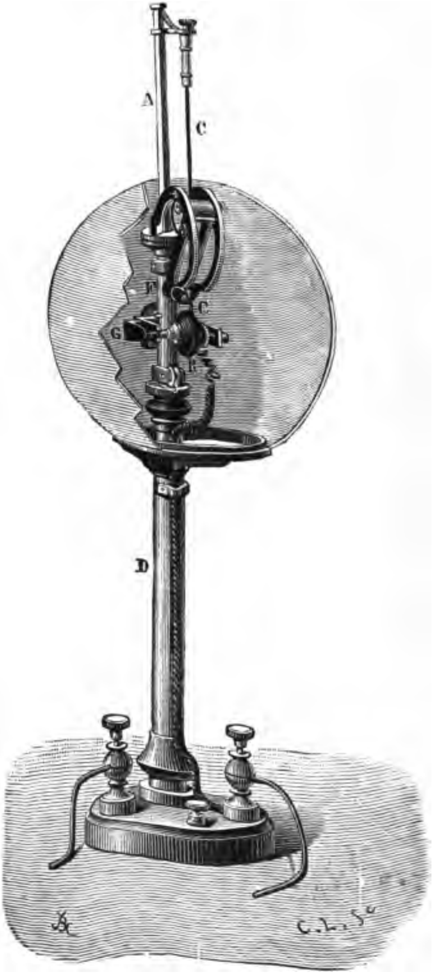


FIG. 51.

of the divisibility of the electric light. The best known form of it is represented in Fig. 51. It is composed, as will be

seen, of a long and slender rod of carbon C C 2 millimetre
in diameter, supported on a heavy carbon-holder A, whic
slides on a hollow column D between four rollers. This ro
rests on a cylinder of carbon R, turning on a horizontal ax
G fixed to the column. A guide, fitted with a brake F, e
closes the rod of carbon to a short distance (6 millimet
about) from the carbon cylinder, and at the same time co
ducts to it the positive current, which returns to the ge
rator by the carbon cylinder and its support. A sec
brake F, placed behind the apparatus and resting on
support A of the movable carbon through an opening m
in the tube D, moderates the action of the weight of
support A, according to the degree of pressure exerte
carbon disc R. For this purpose, the support of the ax
this disc forms a rocker, and on the side of the rocker opp
the disc R is fixed the second brake, of which we are spe

The point of contact of the rod of carbon with the cy
is placed a little eccentrically, in relation to the vertica
ing through the axis of the cylinder, so that at each lo
of the system from the consumption of the rod, a sma
gential impulse may be given to the cylinder, which
it to make a slight movement that suffices to throw do
ash accumulated at the point of contact. Without th
caution, this ash might interfere with the brilliancy
light, at least with the impure carbons which are at
in use.

The problem which Reynier undertook to solve
may be seen, to make a long slender rod of carbo
descent towards its extremity, and while wasting at t
to be moved forward continuously and regularly.
taken from the French patent of the 19th Februar
clearly explains the data of this problem.

"A cylindrical or prismatic rod of carbon C," says R
"is traversed between *i* and *j* by a continuous or al

---

* See *le compte rendu des séances de la Société de Physique* f
July, 1878, p 96.

t, intense enough to make this portion incandescent. The t enters or leaves through the contact *l*, and it leaves or through the contact B. The contact *l*, which is elastic, the rod laterally; the contact B touches it endways. these conditions, the carbon wastes at its extremity *j* than at any other place, and tends to become shorter. quently, if the carbon C is continually pushed in the direc- f the arrow so as to always press on the end contact B, it lvance gradually as it is consumed by sliding in the lateral ct *l*. The heat developed by the passage of the current in d is greatly increased by the combustion of the carbon.

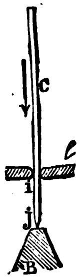


FIG. 52.

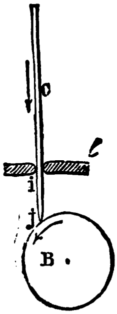


FIG. 53.

In practice, I replace the fixed contact by an end contact B, . 53, which removes the ashes of the carbon. The rotation the end contact is concomitant with the progressive move- nt of the carbon rod, so that the position of the latter on the l contact acts as a brake on the moving mechanism.

'The principle of this new system of lamp having been esta- shed, it was easy to invent simpler arrangements for carrying ut. The samples which I have the honour of laying before Society will explain themselves at a glance. The progression he carbon C and the rotation of the end contact B are obtained the descent of the heavy rod of the carbon-holder.* To wind the lamp, this rod has merely to be lifted up. The rod of

---

Comparative experiments made by Reynier prove that the renewal of end contact is indispensable for obtaining a somewhat prolonged action ı the ordinary carbons of commerce.

carbon is put in its place without any adjustmen apparatus for regulating.”

Previous to constructing the form of la described, Reynier had contrived a more com

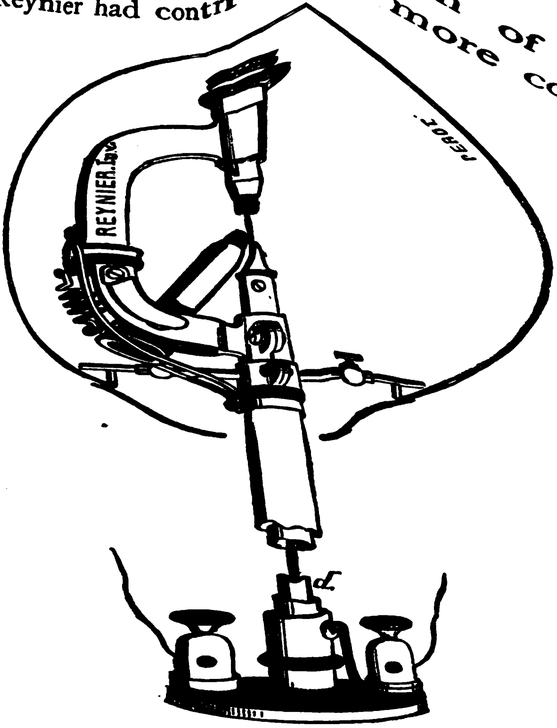


FIG. 54.

in which the carbon cylinder was moved by a mechanism, checked by the pressure of the carb end of which formed a brake, so that the cloc only as the carbon consumed. But he soon problem admitted of a simpler solution.

Quite recently Reynier has given his lamp the in Fig. 54, which yields the best results. In this teral contact has a less complicated arrangement, and eight P which acts on the movable carbon to produce nd contact, is placed above the upper end of the carbon. y therefore be selected as required. The end contact is fixed instead of turning round. The arrangement to the apparatus enables it to be suspended from a g. It can also be placed horizontally : in that case a g propels the movable carbon.

periments made at Sautter and Lemonnier's, with ten ier lamps and a Gramme machine with a speed of 930 , gave the following results in a circuit represented by metres of copper wire of 3 millemetres, or 30 metres of raph wire :

er of lamps tension.	Indications of the galvanometre.	Luminous intensity of each lamp.	Total yield of light.
5	25°	15 jets	75 jets.
6	22°	13 —	78 —
7	20°	10 —	70 —
10	15°	5 —	50 —

Serrin's regulator gave under the same circumstances, with deviation of 21°, a luminous intensity of 320 jets.

As regards total luminous intensity, the use of incandescence mps is therefore less advantageous than that of arc lamps; but ith the former there is the advantage of the division of the ght, and the possibility of obtaining it with comparatively nall electrical power. They consume about 10 centimetres f carbon per hour; but by taking larger carbons and arrang ig the generators for quantity, this consumption may be uch reduced. In the experiments made at the *Société 'encouragement*, six lamps could be lighted with the current om 25 double Bunsen cells. Their light through ground ass globes was soft, and appeared about equal to that of o or three gas-jets. They could be lighted and extin- ished at will.

In the year 1876, S. A. Varley had patented a lamp on a ilar plan which we show in Fig. 55, and which is de- ibed as follows :—

"A rod of carbon T rests gently by its weight an its carrier on the periphery of a roller of retort c and the *imperfect* contact thus produced gives ris incandescence and combustion of the stick of carbo extremity."

We may remark, however, that with this arrangem which the transmission of the current to the movable carbon is not produced by a sliding contact, placed at a short distance from the point, that the light is only produced at the point of contact, and it can be but very feeble, whilst with Reynier's system, in which this sliding contact exists, the portion of the carbon between it and the roller is heated to incandescence. It appears also, on an attentive examination of the patent, that the carbon roller N was made of alterna sulating and conducting portions; and as it was sub to a rapid rotatory movement, the light was the resu series of sparks which were produced at the momen passage of the carbon T on each of the insulating po

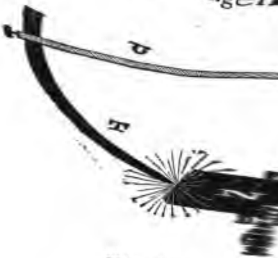


FIG. 55.

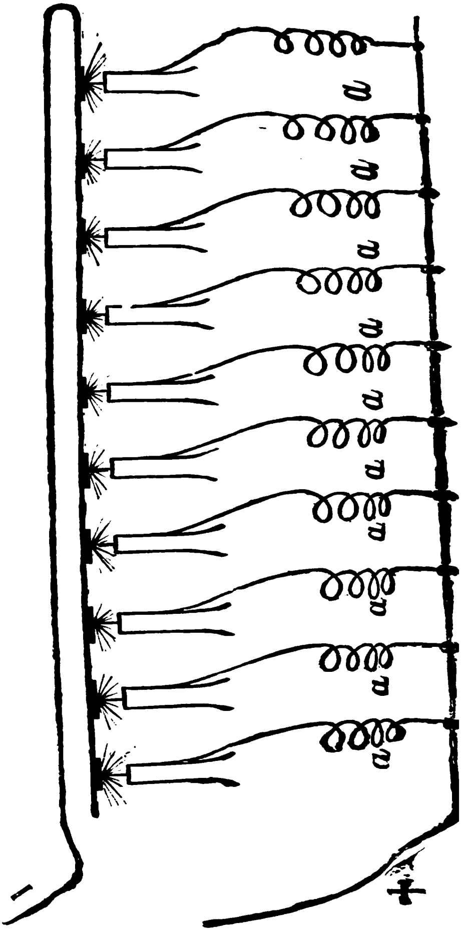
Werdermann's Lamp.—Werdermann's lamp is ciple merely Reynier's lamp reversed; but this arra is more practical for public illumination, for whic vol specially intended, and it makes use of the action. It is represented in Fig. 56.

This system consists essentially of a slender a moving within a metallic tube T, which serves fi guide and conductor of the current. A collar w lower part connects it—by means of two cords pu the tubes by two grooves and pass over two counterpoise P that tends constantly to raise the to keep it lightly pressed against a large carbon

which is kept in a fixed position by a ver-
This support is fixed to a kind of funnel-
which receives the ashes from the com-
s a glass globe to be fitted to the lamp.
ts disc is connected with the negative pole
nd the metallic guide T of the carbon
pencil corresponds with the positive
pole, so that only the portion of the
carbon between the tube and the
upper carbon is brought to incan-
descence. This incandescence is in-
creased by the action of the small
voltaic arc which, as we have said,
is formed at the point of contact of
the two carbons, and it is increased
also by the combustion of the at-
tenuated carbon. The upper carbon,
by virtue of its greater mass, neither
burns nor changes. The action of
the counterpoise is regulated by
means of a spring R provided with
an adjusting screw, which, by press-
ing more or less on the part of the
tube surrounding the carbon, acts as
a brake. The greater or less pres-
sure of this brake depends on the
formation of the voltaic arc between
ons, or merely on the incandescent effects,
his circumstance that the difference between
; and Reynier's system specially resides. In the
able carbon is too contracted to take part in
of an arc, whilst in the other this carbon is
e for this effect to be produced; and thus the
he movable carbon may without inconvenience
for the purpose of making it last longer. In
ns of the Werdermann lamp the upper disc of

carbon has been advantageously replaced by a disc of copper.

Experiments made in England with a Gramme machine arranged for electroplating and worked by a steam engine of (it is stated) two horse-power,* gave, according to Werdermann, the following results:—



"1°. When the current of the machine was distributed between two lamps, the brightness of the light was equal to that of 360 candles. This light was white, and apparently free *from the* blue and red ray *so often per*ceived in the light of *the* voltaic arc. *It was, be*sides, perfectly *steady.*

"2°. By placing in the circuit 10 derivations, each corresponding with one lamp, as shown in Fig. 57, 10 luminous centres could be obtained, each representing about 40 candles. In order to render the action steady, coils *a a a* of small resistance *are* interposed in each de*riv*ation. Under these conditions the resistance of each l was 0·392 ohm, and therefore the total resistance of the ci was only 0·037 ohm.

---

* According to the particulars sent to me, this power should be gre

3. The consumption of the carbons in the smallest pa
of the lamps did not exceed 2 inches an hour, and for the
pattern 3 inches. A length of one metre might be used. T
were Carré carbons."

With this system, and for that matter with Reynier's syst
also, all the lamps could be lighted or extinguished at o
or successively; and as their brilliancy cannot be great, tra
parent instead of ground glass globes may be used. T

Fig. 58 shows the commutators in each derivation, fo
throwing into it the resistance a', for the interruption of th
circuit, and for direct transmission; they are metallic rings,

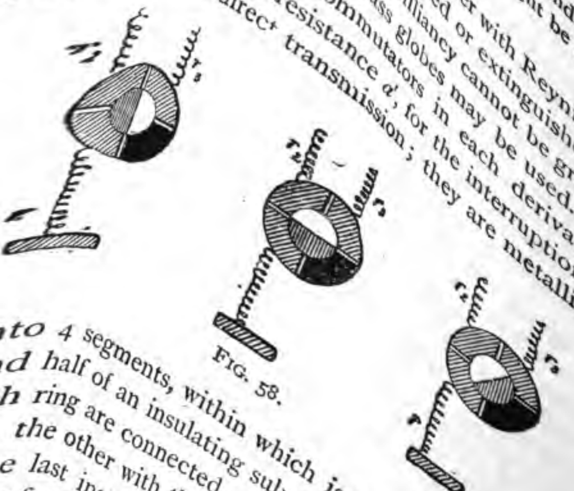


FIG. 58.

divided into 4 segments, within which is placed a plug half of metal and half of an insulating substance. The two upper parts of each ring are connected, one with the upper carbon of the lamp, the other with the lower carbon; but the connection in the last instance is effected through a resistance equal to that of the lamp, or 0·392 ohm. The lower part on the left is connected with the positive wire, and the lower part on the right is made of ebonite. When the plug is in the first position shown in the figure, the current traverses the lamp directly, because the communication is established by the metallic part between the two metallic sectors at the left; when it is in the second position, the current no longer passes through the carbons but through the resistance coil; and as this is equivalent to that of the lamp, there is no change in the distribution of electricity. Finally, when the plug is in the third position, the circuit is interrupted, an lamps benefit by the portion of the current th viously passing through the lamp.

Besides the resistances just spoken of, there placed in the course of the positive wire of eacl which are indicated in Fig. 57, and serve to brilliancy of any particular lamp.

This system of electric lamp has lately be London for lighting the South Kensington Mu it is said to have produced a well-spread lig quality, an agreeable softness, and a remarkabl (See the journal *La Lumière électrique* of th 1879, p. 72.)

Some very successful experiments were also m in which six to eight lamps were lighted by th an *Alliance* machine. It is asserted that it wil to light a much greater number with lamps pattern and with a particular arrangement of t We shall wait and see the result for ourselves nouncing on this matter. We have just learnt Gramme machine, driven by a gas engine of 6 h it has been found possible to light 15 Werdermann carbons of which were 4·5 millimetres in diameter, giving a light of 25 Carcel lamps. It was, howe form of this kind of lamp which gave this result, form is not sufficiently known for us to describe (See Note D at the end of this volume.)

Trouve's form of Reynier's Lamp.—Trouvé given a new arrangement to Reynier's lamp, which what that of Werdermann, and at once rather practi economical. Fig. 59 will give a precise idea of it. small carbon B, which gives the incandescence, is in a long tube with a slit all its length, which allow movable portion D to push the fine carbon against the sive cylinder D under the influence of a counterpoise

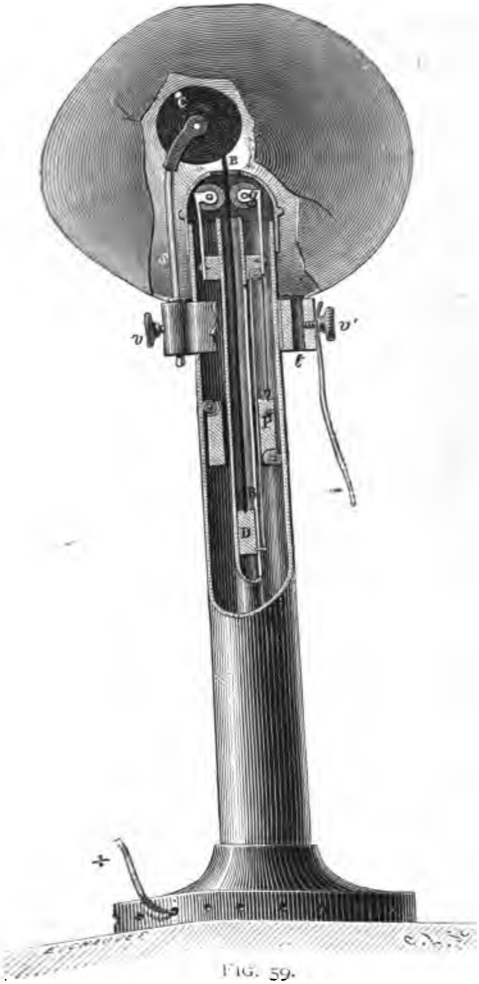


FIG. 59.

vided with rollers. This fine carbon is guided between two spring rollers *g*, which also carry the current to it. The cylinder c is of copper, and presents itself to the carbon in such a manner as to be able to turn by the tan sure against it, in proportion as the illuminate consumed. This lamp works well, and can henc plied to domestic illumination under the influenc from 6 Bunsen cells. The rod of carbon is of a diameter than those used by Reynier.

E. Arnould has lately invented a lamp the ar which is exactly that of the preceding apparat much less excellent conditions, and yet certai have not hesitated to announce it as something

Ducretet's form of Reynier's Lamp.— ment of the kind just alluded to has also been given to Reynier's lamp by Ducretet. In this form, shown in Fig. 60, the rod of carbon C M, instead of being pushed by a counterpoise, is plunged in a column of mercury, filling a long iron tube T, which forms the body of the lamp. A cap and an elastic collar B guide the rod, and, as well as the mercury, impart to it the positive polarity. A carbon cylinder H, supported by a metallic arm S, movable in a socket with a regulating screw, allows any required length to be given to the incandescent portion. The current reaches the apparatus by the conductor *t*, and leaves

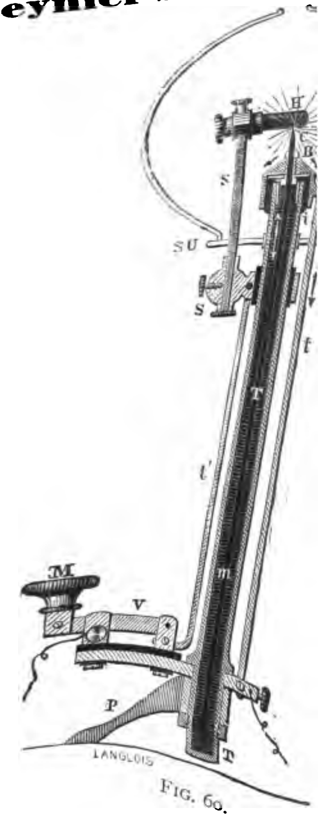


FIG. 60.

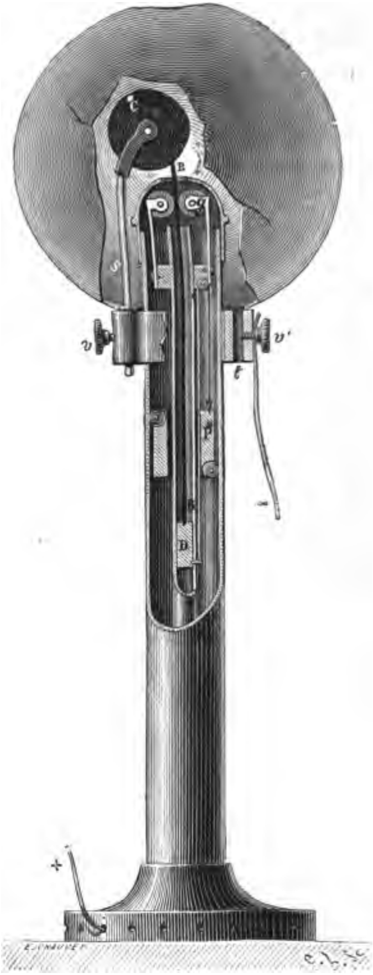


FIG. 59.

vided with rollers. This fine carbon is guided between two spring rollers *g*, which also carry the current to it. The cylinder C is of copper, and presents itself to the carbon in

such a manner as to be able to turn by the tange
sure against it, in proportion as the illuminated r
consumed. This lamp works well, and can hencefort
plied to domestic illumination under the influence of a
from 6 Bunsen cells. The rod of carbon is of a more s
diameter than those used by Reynier.

E. Arnould has lately invented a lamp the arrangeme
which is exactly that of the preceding apparatus, but u
much less excellent conditions, and yet certain newspap
have not hesitated to announce it as something new.

Ducretet's form of Reynier's Lamp.—An arrangement of the kind just alluded to has also been given to Reynier's lamp by Ducretet. In this form, shown in Fig. 60, the rod of carbon C M, instead of being pushed by a counterpoise, is plunged in a column of mercury, filling a long iron tube T, which forms the body of the lamp. A cap and an elastic collar B guide the rod, and, as well as the mercury, impart to it the positive polarity. A carbon cylinder H, supported by a metallic arm S, movable in a socket with a regulating screw, allows any required length to be given to the incandescent portion. The current reaches the apparatus by the conductor *t*, and leaves

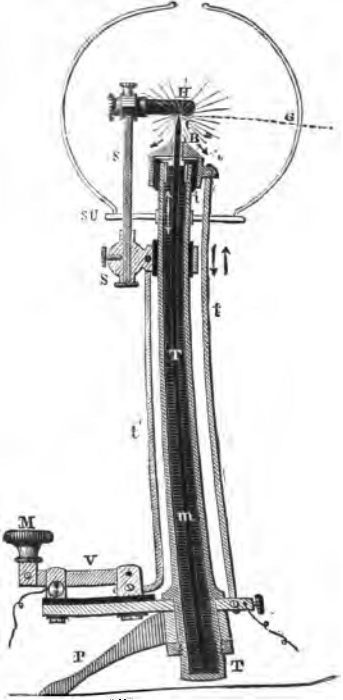


FIG. 60.

: conductor *t* and the interrupter M V. In order to
ıe poisonous vapours emitted by the mercury in con-
e of becoming heated, the cap B is insulated from
T by means of a substance not a conductor of heat,
ommunicates with the base of the lamp through the
onductor *t*, which, being a good conductor of heat,
: and withdraws it from the mercury.

stem, by its simplicity, permits the lamp to be very
ade. It had, however, been already devised by
ho had pointed it out amongst the arrangements
be given to his apparatus.

'**s Lamp.**—In order to obtain a longer duration
ıg of the preceding lamps, Tommasi arranged
evolver. For this purpose, the lamp is formed
e about 3 centimetres in diameter, turning on
pporting five carbons of 30 centimetres length,
after another, are by a rotatory movement
ontact with the carbon disc of the negative
the light is produced for eight or ten hours.
vement of these carbons is effected by mer-
n the tube, as in the preceding system, and,
igno, the light thus supplied is very uniform
is lamp has the shape and size of an ordi-

mp.——The reputation that Edison acquired
the phonograph was the cause of con-
of disasters, when some time ago he an-
l finally found the long-sought solution
had division of the electric light. He was
the and in America, as well as in England and
of the gas companies fell enormously.
ares the American newspapers were often
that false news; and since the phonograph
of the denials with which its announce-
uted

ment was greeted, people ceased to recollect the pro canards Americains. Be that as it may, this pompou nouncement caused many losses, and that at three diffe times. People have now recovered from their fears, and always happens, have passed from one extreme opinion to opposite. The truth is, that if Edison's invention were first but a very small matter, it might some day gain impor ance ; and according to the information I have received from ocular witnesses, the last patents of Edison's, which require not less than 200 pages for their description, might contain discoveries of the greatest importance. It seems that even Edison's failures have not discouraged American capitalists, and that they have put at his disposal not only all the necessary amounts, but also engineers of all kinds, electricians, mechanicians, chemists, &c. According to the persons who gave me this information, Edison has constructed a dynamo-electric generator superior to all those we have mentioned, and capable of utilizing 90 per cent. of the motive power.

Without attaching too much importance to these accounts, it must be admitted that a man so ingenious as Edison has not for so long a time studied a question without making something of it; and while waiting until the new patents are published, we must meanwhile give some account of the lamp which has fluttered the financial world. It is represented in Fig. 61.

According to Edison, the loss which is involved in the division of the electric light is not peculiar to this kind of light, but also occurs with gas when the elements of its flow are placed under the like conditions. Thus, if a great number of gas-jets are opened and the total amount of light measured, a smaller luminous intensity will be found than that resulting from a small number of these jets under the same pressure of gas. But if that pressure be suitably regulated, things may be so arranged that this loss would not exist.

"Now," says Edison, "properly arrange the condi of the electric current, and you can do for hich has been done for gas." This reason-

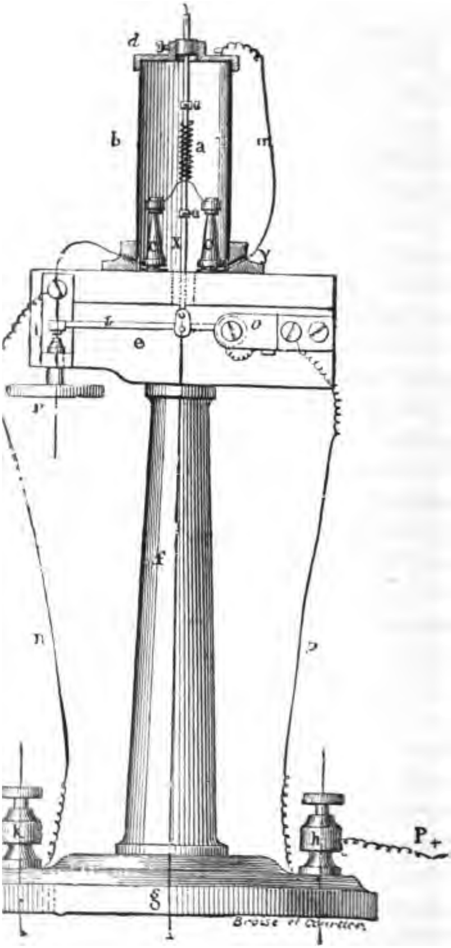


FIG. 61.

ly up to a certain point, for the conditions ensity of a current with or without derived currents are well known, and the arrangement of the generator in any given case is indicated perfectly by Ohm's formulæ. As regards this matter, we do not think that Edison can discover anything more than we know already; and we believe that it is rather by the material arrangements of his lamp that he will have any chance of arriving at the solution he is seeking. Now Edison's lamp, which has many very different forms, consists of the following:

The principle of the lamp, which is represented in Fig. 61, is the incandescence of a spiral of platinum wire *a* alloyed with iridium. And in order to prevent the spiral from burning when its temperature exceeds a certain point, Edison places within the spiral a metallic rod G, which by dilating causes a contact to be made at *i*, by means of the lever S, precisely at the moment when the heat is about to reach that degree. The current is then *derived* through this contact, and immediately lowers the temperature of the spiral, which causes a disjunction of the derivation and arrests the cooling. The spiral then begins again to be heated, and is thus maintained at a temperature which can vary only between very narrow limits, which may be regulated by the greater or less separation of the contact piece *i* of the derivation, by the resistance of the derivation, or by a resistance regulator variable with the pressure, based on the principle which Edison has applied to telephonic transmitters.

Can a platinum spiral by this means acquire a temperature sufficiently high to produce light? This appears the more doubtful from the fact that De Changy did construct a very ingenious regulator under similar conditions, and that, nevertheless, his spirals were volatilized when they were heated to such a point as to become luminous.

It is true that, according to the American journals, Edison has discovered a new metallic alloy, having its fusing point much higher than that of any known metal.*

---

* According to Edison's last patent, the incandescent spiral is formed of platinum and iridium, and is covered with a metallic oxide, either of cerium,

lighter of Reynier's Electric Lamps.—
avoid the inconveniences which may result from the
ction of an electric lamp—an extinction which may
ve that of all the rest of the lamps in the same circuit—
ier arranges an automatic system of permutator, the
of which is to light other duplicate lamps placed in
eighbourhood. This system consists of a kind of
o-magnet relay which sends the current of one circuit
another, when the armature of this relay, being no
r attracted, touches its limiting stop. If for this pur-
two duplicate lamps are used, as Reynier proposes,
lamps are introduced into two derivations of equal
nce arranged between the two conductors of the
tor, and the relays which are to act in these lamps
erposed in the circuit of the first lamp: the contacts
se relays are also arranged so as to establish the com-
ation of the derivations with the circuit at the separation
n relay. When the first lamp is lit, the electro-mag-
f the relays being active, the communications of the
ions with the circuit are severed, and the lamp works
but if the latter should be extinguished, either by
nsumption of the carbons or by accident, the current
ediately sent into the derivations; but as there is
ut one relay which is active, there is only one of the
te lamps at work, and it is only when this one is in
n extinguished that the third is lighted.
s system may readily be arranged to suit the various
n which the luminous central arc is connected with the
pal circuit.

---

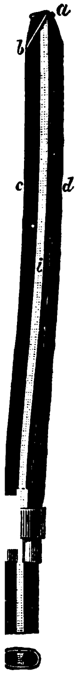
ium, calcium, magnesium, or of some other metal—*i.e.*, an oxide not
d by a high temperature. The effect of this covering is designated by
on by the name of *pyro-insulation*, and in order to cover the wire it
ces to dip it into a solution of one of these oxides, then into an acid,
to pass the spiral through the flame so as to evaporate the aqueous
tions and leave only the oxide on the wire. (See the *Telegraphic Journal*
15th July, 1879.)

ELECTRIC CANDLES.

Jablochkoff's electric candles, which have lately been much spoken of, are certainly not the ideal of the elec light; but on account of the absence of all mechanism, the comparative regularity of their action, they can be app to public illumination, and assuredly this could not been done with any electric lamp invented up to that t It is they, and the influential company working the inven that have enabled those beautiful experiments to be u taken, and those splendid illuminations to be made o *Avenue de l'Opéra*, of the *Arc de l'Étoile*, of the *Chamb* *Députés*, of the shops of the *Louvre*, of the *Théât* *Châtelet*, &c., which astonished all the visitors to Paris d the Exhibition of 1878, and proved that electric lighting not the chimera that those interested in gas companies w to think it. It was the Jablochkoff lamps that excited rage for electric lighting in every country, which will, as as fate, shortly lead to the substitution—or at least partial substitution—of gas illumination by electric illumi tion. These candles are, moreover, much used, being no daily lighted in more than 1,500 lamps. We must there fore devote a long chapter to them.

If two perfectly straight carbons are placed side by side parallel to each other, and separated by an insulating layer capable of being fused or volatilized by the passage of the electric current between the two carbons, a lamp without machinery is obtained, which gives light like a candle, that is to say, it burns progressively until the two carbons are entirely consumed. This is the principle of the Jablochkoff candle represented in Fig. 62.

Numerous experiments have been made to ascertain what is the best insulating material to place between the carbons, nd what are the best dimensions for them. After iany trials, preference has been given to plaster of Paris as ie insulator, and to Carré's carbons 25 centimetres long nd 4 millimetres in diameter. When giving a light equal o from 25 to 40 gas-jets, these candles will last for one hour and a half; but we shall presently see that by a very simple arrangement the light founded on this system may be made to last as long as may be desired. A Jablochkoff candle is, then, composed of two insulated Carré carbons *c*, *d*, 25 centimetres long, slightly pointed at their upper extremities, and separated by the insulator already mentioned, provided at its upper end with a thin layer of lamp black for conducting the current when the candle is first lighted. This layer is made of black lead mixed with gum, and the candle is charged by merely dipping its end in the mixture. At first the two carbons were connected by a plumbago point kept in its place by a piece of asbestos paper; the preceding plan is now found to be much simpler. At the lower end the carbons are fitted into copper tubes, by which they are connected with the circuit when the candle is placed in the chandelier; these tubes are inserted in the piece M (made of a silicate or other suitable substance) so as to prevent the carbons from separating from their insulating partition. Before the manufacture of Carré's candles was established on the large scale, a candle like this cost 75 centimes, a rather high price; but now that the cost of these carbons nuch less, the candles can be made at a cheaper rate— haps they may some day be had for 20 centimes. We not now calculate the cost of the electric light on the which served for the estimates of the early experiments.*



G. 62.

---

lready the Company sells these candles to private persons at 50 nes.

The manufacture of these candles, which is conducted on the large scale* at No. 61 *Avenue de Villiers*, is very interesting, especially the way in which the insulators are made. A thin layer of sculptors' plaster mixed with sulphate of barium, and so tempered as not to set quickly, is spread upon a marble table slightly oiled, by means of a mould made of a notched plate of zinc fitted into a sliding handle. By drawing this mould along, the plaster in front of it is spread on the marble in the form of grooves and projections to the length of about 2 metres. When the mould has been passed along several times, a fresh quantity of plaster is placed in front of it, which increases the thickness of the projections, and after five or six operations of this kind these projections have exactly the thickness of the teeth of the mould which is that suitable for the insulators. The sides of the insulators are, of course, made slightly concave to receive the cylindrical carbons. Their thickness is generally 3 millimetres between the carbons, and only 2 millimetres in the other direction.

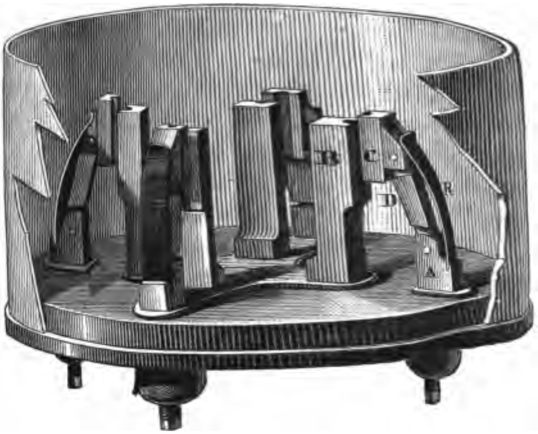


FIG. 63.

Fig. 63 shows the way in which the Jablochkoff candles are held in the lamp. There are places for four in the figure, but the number may be larger; the lamps in the Place de l'Opéra can hold twelve. Each support consists o two brass uprights, one of which A C is double-jointed, and ends in a shoulder C that will exactly fit the piece to be placed between it and B. A strong spring R presses C towards B. The two pieces B and C are provided with cylindrical grooves which receive the metallic terminals of the candle. As these pieces are electrically insulated from each other and provided with binding screws, it is easy to connect the two carbons into circuit.

---

* Six or eight thousand are made per day.

Several plans may be used for obtaining continuity of illumination; the simplest and best is to connect one of the erminals of each lamp to a commutator, so that, after the ombustion of a candle, the current may be made to pass nto the next one by simply turning a handle. This commu- tor, in the apparatus at the *Avenue de l'Opéra*, is placed thin the support of the lamp, and an attendant comes ery hour and a half and turns the handle. This commu- or is double, in order to make a double change, when two dles are burnt in the same lamp, as in the lights at the *ce de l'Opéra*. The construction of the apparatus is very ple; it consists merely of a wooden disc on which are d in a circle as many metallic plates as there are candles; ndle with a spring turns on a metal pillar in the centre e disc, and the spring pressing against the plates esta- es a connection between the central pillar and the plate ected with such candle as may be required.

sides this plan several automatic arrangements have invented, but they have not been generally adopted ctice, which has retained the commutators just de- d. One of these arrangements, represented in Fig. 64, ted of a bent lever M O *m* turning at O and carrying at nd the platinum wire *f* leaning against the insulator of ndle A′ B′, and at the other end provided with a con- iece M, which, by touching another piece P, closed the through the next candle A B. A spring *r* acting on ver kept the wire *f* (by which the contact of M and P revented), pressed against the candle; but when the

candle was consumed down to the wire, the latter w
longer supported, and the lever turned until M and P
brought into contact. As each candle was provided w
similar apparatus, the current was transferred successi
from one candle to another, without any intervention.

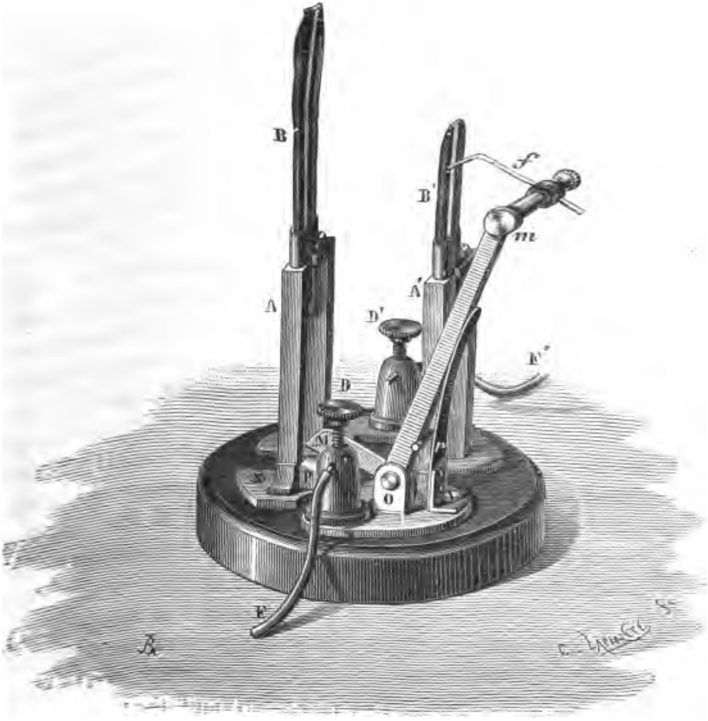


FIG. 64.

In another plan, the change was effected by an electro-magnetic escapement with clockwork, which came into action when the current was interrupted by the extinction of any of the candles, or by a touch from an attendant.

Jablochkoff has, however, lately discovered that no me

anism need be used to obtain the successive lighting of
e candles. When the circuit connections are made simul-
aneously through all the candles, one of them will always
ransmit the current more readily than the rest, and that par-
icular one being lighted by the heat developed, the current
will pass almost entirely through the arc, the loss through
the other candles being quite insignificant.

The light given by the Jablochkoff candles is very uniform, at least so long as the Gramme machines which supply them work regularly. This light may, however, have a more or less white colour, according to the nature of the insulator between the carbons. If this insulator is made of kaolin, the light has a somewhat bluish tint; if it is made of plaster of Paris, the colour is rosy and more agreeable.

The comparative steadiness of the luminous part in the Jablochkoff candles is owing to the carbons being kept always at the same distance from each other, without any motion, and the small derivation of the current due to the fused insulator which contributes to the steadiness of the light. In consequence of this derivation, the electric current is less weakened than when the carbons are separated by air, and therefore a larger number of lights can be interposed in the same circuit. The flame, too, which accompanies the light appears to enlarge the luminous focus, so that the illumination is better diffused and with less shadow than that given by regulators. Opinions vary as to its intensity; it is generally believed that with equal currents the light of the candle is considerably less intense than that of the regulator. Jablochkoff contends that this is not so, and that in the experiments of comparison from which this conclusion was drawn, the candle was under less favourable conditions than the regulator, which automatically adjusts itself for the best effect. In support of this statement, he mentions the experiments made by Fichet, one of the jury at the *Exposition*, who, in order to remove any doubt in the matter, proceeded as follows:—After having measured the illuminating power of a

candle having carbons 10 millimetres in dia
placed the same carbons in one of Serrin's regul
justed so as to give the same length of arc. The c
thus being the same in each case, he found that the
intensity was also the same; and he points out that
employed in volatilizing the insulator was not entirel
is generally supposed. With certain insulators, par
with kaolin, there may be, according to Jablochko
diminution of light from the somewhat considerable
tion of the current through the fused part of the in
but with plaster insulators this inconvenience does nc
and above the candle there is a flame, which he co
useful. Be that as it may, these candles are not exce
in being attended with a loss of electricity, for in th
lators there is also a loss of current, due to the introd
into the circuit of a coil of more or less resistance. I
have seen that the Lontin arrangement, by derivatio
great measure avoids this inconvenience.

The Jablochkoff candles require to be used with alter
reversed currents: and we have seen that to obtain
from the Gramme machine it was necessary to inv
special machine, which at the same time would allo
action to be distributed over several circuits. It is ea
see why the currents must be reversed, if we remember
with direct currents one of the carbons (the positive
would be consumed quicker than the other, and the dist
between them would gradually increase, until it would be
so great that the light would go out. Jablochkoff ass
however, that this may be prevented by increasing
diameter of the positive carbon sufficiently to make it
as slowly as the other. This plan has not hitherto been t

In order to obtain a slower rate of consumption, Jabl
koff has lately used metallized carbons. We have seen (p. 1
that this plan, which was invented by Reynier, has given
cellent results, and in experiments recently made at Ger
the candles were thus prepared. The metal was, howe

the parts of the carbon in contact with the
are told also that in America this metalliza-
eemed sufficient, and the carbons were further
laster to keep the metal from oxidizing—ap-
ithout advantage.

en that to light the Jablochkoff candles the
first be passed through a secondary conductor.
is once established, this secondary conductor
and nothing more remains by which the candles
ted again if they went out. This would be an
e if there were not at hand a commutator and
serve. But Jablochkoff has contrived a plan
re is a secondary conductor between the car-
the arc is extinguished. He mixes very fine
s with the insulating plaster, and when the latter
these are also vapourized ; and when the light is
, the copper deposited on the insulator is a suffi-
uctive layer to re-light the candle.

elled glass globe is used with the Jablochkoff
n these are applied to public lighting, and then
is has the appearance shown in Fig. 65, where
ction and part in elevation. This arrangement,
uses a great loss of light, for 45 per cent. is
the globe. It is true the light thus diffused is
s for lighting, but these contradictory conditions
sfied by using, instead of the globes, double re-
instance, a kind of funnel of ground glass sur-
e candles below and above a hemisphere of
lass; above this should be placed a reflector of
lass or porcelain, which will send down again the
ys reflected by the internal surface of the funnel.

light globes are, however, now being improved.
de them of opaline glass, absorbing only 35 per
ight. At Baccarat, globes have also been made of
, which have only a comparatively small absorbing
this absorption may be reduced to 10 per cent.

by using a globe of waved or wicker-work glass. Clémandot has also made globes of transparent glass in which the diffu-

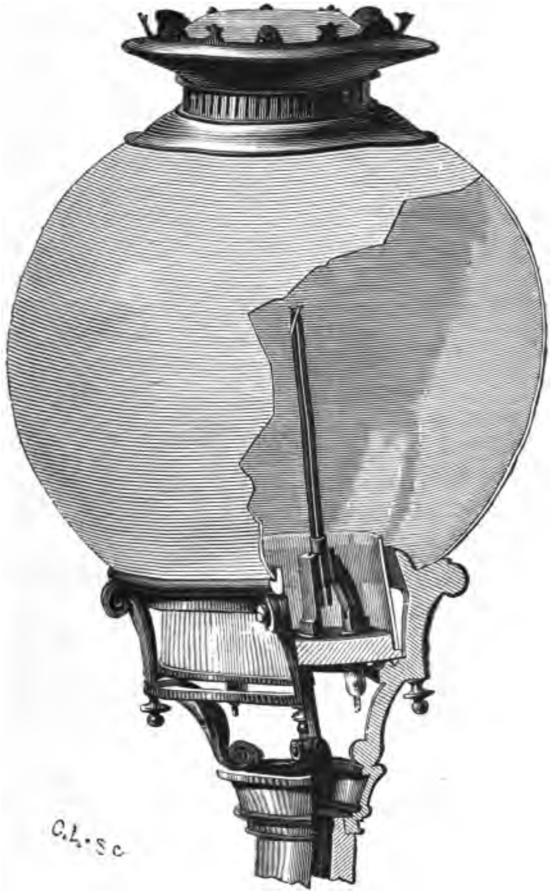


FIG. 65.

sive effect is produced by a layer of fragments of glass placed between two spherical surfaces one within the other. These globes absorb, according to the maker, only 25 per cent.

ut it may be feared that some inequalities may ur and destroy the uniform diffusion of the light. nditure of motive power for 20 Jablochkoff candles y a dividing Gramme machine is, according to a esented in May, 1879, to the London Metropolitan Works by Bazalgettes and Keates, as follows:

only one circuit used	13·17 horse-power.
two circuits used	17·91 „
three circuits used	20·75 „
four circuits used	23·53 „

for each candle

5 candles	1·59 horse-power.
10 candles	1·27 „
15 candles	1·03 „
20 candles	0·92 „

m these numbers the work required to drive the ma- s *in vacuo* has been deduced.

cording to the same report, the luminous power of these lles in Carcel lamps is:

For the naked light	39·8 horse-power.
For one with frosted glass...	27·9 „
„ opaline glass...	16·5 „

hence it would follow that the opaline glasses absorb 59 er cent., and the frosted glasses 30 per cent. of the emitted ght.

In order to increase the illuminating power of his candles, Jablochkoff has used condensers of large surface, the effect of which is to increase the tension as well as the quantity of the alternating currents. For this purpose he puts a conductor from the generator in communication with the homologous armatures of a series of condensers, the other armatures of which correspond separately or collectively with the different candles connected with the generator. Both for quantity and tension the effects are superior to those produced by the action of the generator simply, and this is proved in the manner following:

If in the path of the current from an alternating-current machine capable of giving a spark equal only to that of 6 or 8 Bunsen elements, there is interposed a series of condensers of about 500 square metres in surface, a voltaic arc of from 15 to 20 millimetres length may be produced, and carbons of 4 millimetres are made incandescent for a length of 6 or 10 millimetres from their extremities. Also, if in the current of an induction coil supplied by an alternating current, and giving a spark of 5 millimetres, there is interposed a condenser of about 20 square metres of surface, a voltaic arc of 30 millimetres may be obtained; and in this case also carbons of 4 millimetres in diameter are made incandescent for a length of 6 or 10 millimetres from their extremities. Finally, a certain number of condensers being given, if the second surfaces of one or of several of them are joined with the second inducing coil of the machine, or with the earth, there will be produced in the apparatus arranged as before effects much resembling those of static electricity.

These effects are what might have been expected, and it was by similar means that Planté, with his rheostatic machine, succeeded in transforming voltaic currents into currents of static electricity capable of giving sparks 4 centimetres long.

Jablochkoff's system of condensers supplies a very simple means of regulating the intensity of the light of the candles while they are in action; for this purpose there is needed merely a commutator by which a greater or less condensing surface may be connected with the circuit.

Each of these condensers when applied to public lighting is made of 25 separate elements, and corresponds with a group of four candles; consequently, these four candles are connected with one of the wires proceeding from one of the armatures, and the circuit is of course interrupted at the condenser.

It may therefore be inferred that the current which supplies the candles is only a current of the return discharge

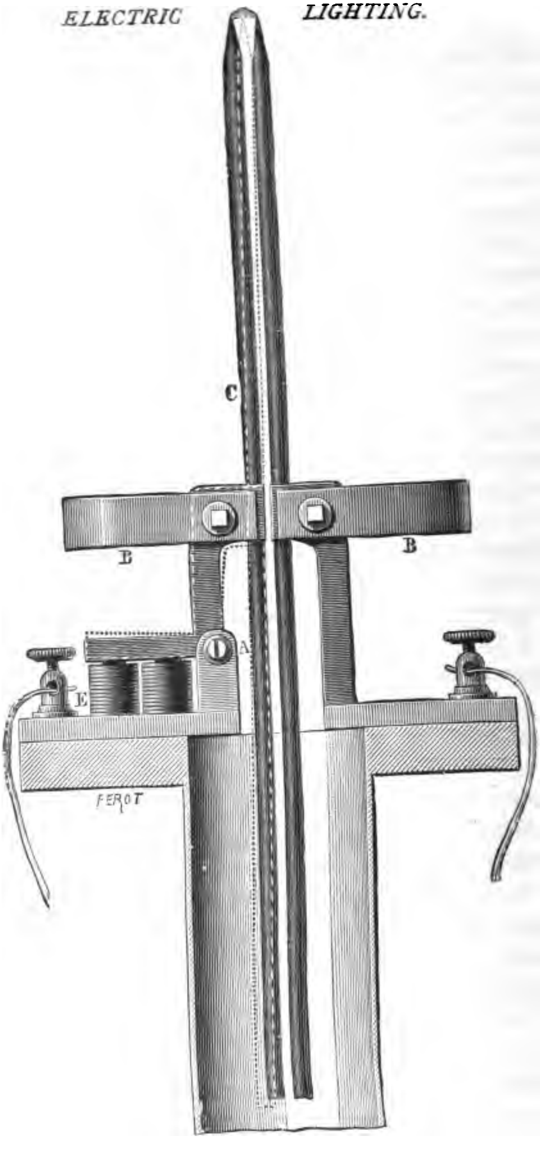
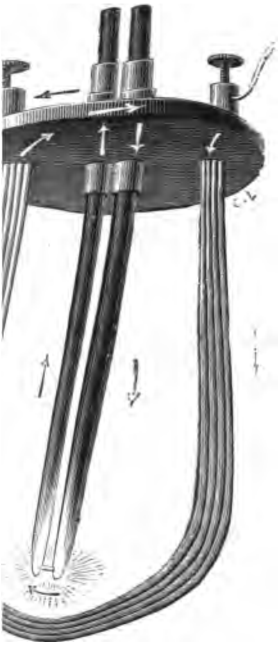


FIG. 66.

each other, and then it causes a greater or less separat which can be maintained, for the movable carbon is s jected during the whole time of its combustion to two op site effects, which keep it always in a position more or l near the fixed carbon, from which position it can vary onl very little. This arrangement seems very nearly the sa as that which Rapieff described in the *Telegraphic Jour* of the 15th December, 1878, and the 1st February, 18 It remains to be seen who is entitled to the priority. T Méritens system is composed of three parallel carbons not contact. The current passes in the outside carbons, and t middle one is merely the means of facilitating the dischar and rendering it uniform. Nevertheless, this system has given regular results; but that of Soligniac, in which fo carbons are used, has been much more satisfactory, and shall speak of it further on. The important condition in these systems is that the two carbons shall never be able assume a perfectly parallel position, for in that case t luminous point may be displaced, and pass from one end the carbons to the other.

One system has been proposed in which the carbons ar inclined and applied one to the other, until they are lighte by being separated by a rod of refractory matter introduce between them, the movement being controlled by an electro magnetic action.

Jamin's Candle.—Of the electric candles invented since the Jablochkoff, none has attracted more attention than the Jamin burner, which is represented in Fig. 67. It is a candle of the same kind as Wilde's—that is to say, there is no insulator between the carbons. The luminous point is constantly maintained at the end of the carbons by the action on the arc of the current itself passing through a conductor beneath the arc, and returned on itself four times, forming a rectangular figure about the carbons. Two parallel currents in the same direction, as we know, attract each other, and therefore it will be understood that the arc is attracted by the of the current passing below it, that it will tend to move rds the fixed conductor, and consequently will be kept e end of the carbons. Jamin thus describes his invention in a note laid before the *Académie des Sciences* on the April, 1879:



'IG. 67.

"I have the honour of presenting to the *Académie* a model of an electric burner reduced to the greatest possible simplicity. The two carbons are kept parallel by two insulated copper tubes, separated by a space of 2 or 3 millimetres; they slide with friction in these tubes, which serve at once to keep the carbons in their places and to convey the current to them. The carbons are surrounded by a circuit of five or six spires wound on a slender rectangular frame 40 centimetres long and 15 wide. I have explained how this circuit, traversed by the same current as the carbons and in the same direction, brings the arc to the end of the carbon points and keeps it there.

"The lighting is done automatically. For this purpose the two ends of the carbons are surrounded by a thin India-rubber band, which presses them together; then a little higher a small ron wire is placed between them, which puts them munication at a single point. As soon as the cir- he current passes through this wire, heats it to elts the India-rubber; the two carbons being parate, and the arc is established with a kind of ons of any thickness up to 8 millimetres may this size the consumption scarcely exceeds 8 centimetres per hour. As it proceeds, the points get near to the supporting tubes; but from time to time they can, without extinguishing the light, be restored to their original position by simultaneously sliding the two carbons in the tubes. In future a mechanism easy to imagine will perform this duty, and as Carré makes carbons 1 metre long, the lamp may continue lighted for twelve hours, a period longer than will ever be required. It will be observed that the carbons are not separated by any insulating material, and that it is not necessary to point them beforehand, or to fix them at their base, or to tip their ends with any inflammable material. They are used as they leave the manufactory. It suffices to put them into the tubes that hold them, and leave them to the directing action of the exterior circuit. There is, in fact, no candle to be made, it is merely a putting in its place of a sort of match which burns by itself to the end.

"The apparatus may be hung up in two ways, with the points upwards or directed towards the ground. The conditions are very different. Let us examine the first case.

"The electric arc cannot, without breaking, exceed a length, which depends on the intensity of the current. Between two carbon points in a horizontal line, it should be straight, because according to the laws of electric conduction, it takes the shortest course and tends to return to that by virtue of a kind of elasticity if withdrawn from it. But it is interfered with by the ascending current of air generated by its own heat; and for that reason assumes the curved form. It is still more strongly interfered with by the directive circuit (in the carbons), and these two actions combine to curve it upwards until equilibrium is attained between them and the elasticity (as it might be termed) of the arc; but they also cause it to become longer, they lessen its resistance to rupture, and diminish the intensity of the current. We see, then, that if they concur in fixing the light at the points of the carbons, it is on the condition of diminishing the limit of length attainable by the arc, or, what amounts to the same thing, the number of arcs that a given machine will maintain.

"It is quite a different thing when the points are turned downwards. While the arc tends to rise up along the carbons, the directive circuit drives it back, and brings it down between the points, which have an interval of 7 or 8 millimetres between

m. The two actions which formerly combined now oppose h other; so far from lengthening the arc, they shorten it; tead of lessening its resistance to rupture and diminishing the ensity of the current, they increase both.

‘ This arc may be said to be compressed between two opposite tions; it is shorter, narrower, less expanded, denser, and conquently hotter, and the number of the lights may be increased. ie Jablochkoff candles, otherwise so well arranged, possess the convenience of having their points upwards. The arcs they rm naturally tend to curve and rise up, a tendency which is rengthened by the electro-magnetic action of the current cending in one carbon and descending in the other: an action entical with that in my directive circuit, though smaller in nount. The burners with the points downwards should therere surpass these candles, as, indeed, experience proves. With machine which is sufficient, with difficulty, to light three candles, easily supply five burners, fitted with much larger carbons, ich burner giving twice as much light as a candle; and as the oints are immersed in the mass of the arc, they are more brilint and of a much whiter colour. Even six lamps may be ghted, but they give a sum total of light less than five do; the imber may be doubled, but there is a loss in the quantity of ght. It is always thus when we try to divide the electric light eyond a certain extent; the division is purchased by a propornal loss.

“ It is interesting to examine the behaviour of these burners· hen the points are upwards, the first lighting is very difficult, cause the arc is at once briskly thrown upwards by the inence of the directive current, which is proportional to the iare of the intensity. When this increases it becomes absoely impossible to light the carbons; we get nothing but a great ne, which immediately disappears with a snap. If the current veaker the light remains, but very diffused, very high, and ays very noisy, on account of the oscillations which take place each inversion of the current. Again, the equilibrium is able; if an accidental current of air for an instant raises the ht of the arc, it cannot be brought back; the limit of its icity is exceeded, and it immediately breaks. In the burners the points downwards the lighting is easy and the equilin stable, for if a movement of the air, or a failure, causes the arc to rise, it is established between the two carbo where they have not been worn away by combust up a position where the interval does exceed 2 or 3 So far from being lengthened, it is shortened; and being lessened, the resistance to rupture and the inte current are increased, and the light is seen to quietly again, and resume its position at the extremities of the if, on the contrary, the current increases, the arc bend comes concave towards the carbons, but its tenden counterbalancing the action of the directive current, i sufficiently elongated to break. The best economical c are obtained when this curve is just sufficiently marke vent the upward movement of the arc. In this case t able noise of the electric light is reduced to its minimum the amplitudes of the vibratory movements are the possible.

"In short, the burner I submit to the *Académie*, with downwards, realizes considerable advantages :—1°. S since it involves no mechanism, and needs no prelimi paration; 2°. mechanical economy, since the number may be doubled; 3°. increase of light, since each of lamps has double the power of the old ones; 4°. quality which is whiter; 5°. a better arrangement of the lamps, throw the greater part of their light downwards, inste towards the sky, where it is useless; and 6°. economy combustibles, since the consumption is less on account thickness of the carbons. All this forms a marked progre the electric light, and cannot fail to strengthen the hold it already taken on public illumination, thanks to Carré's carb to Jablochkoff's candle, and to the progress made in machi

Jamin has quite recently added to his burner an ele magnetic arrangement which, as in Wilde's system, en the candle to be automatically lighted, and prevents tinction. For this purpose he makes the upper part multiplie that surrounds the candle, where it passes the plat by which the system is supported, go betwe branche of a plate of iron bent into a horseshoe form branches consequently constitute while the current poles capable of attracting soft iron armatures. These atures are provided with stops and with opposing springs, are each attached to a jointed arm placed in a different ection, and connected on either side with one of the bon-holders. Now it follows from this arrangement that current sent out of the machine produces a double action, and gives rise to a movement that becomes vibra- by reason of the rapid succession of the currents, and movement, by bringing the carbons nearer to and further each other, keeps them continuously lighted. This move- may moreover be more or less marked by means of the and springs of the armature. (See, for details of this gement, the journal *La Nature* of the 20th September,)

company which manufactures the De Mériten's ma- now devotes some attention to fabricating carbons electric light, and candles of a new form invented by ac, which, it seems, yield very good results. These have four carbons of unequal diameter, separated ach other by an interval of half a millimetre, are ed together in the same plane by two insulating atilizable bands. The two outside carbons have a iameter than the others (4 millimetres), which are millimetres in diameter; the outside carbons are, fitted into copper sockets, by which the electric cation is made with the lamp. Finally, the four are at their bases connected by plaster of Paris, upies all the space between the two sockets. It nat candles on this plan can only work well with ns, and that those in which only three are used bandoned.

seen (p. 139) that Alkelmer sought to diminish ce of electric carbons by introducing metallic een the sides of the insulator and the carbons. plates also possess, according to him, the very tage of enabling the candle to be automatically

re-lighted; but in that case it is necessary that the
should be made of a moderately conducting substa
resistance of which is calculated accordingly. This a
ment moreover enables the current to make a deri
when the light goes out, and this prevents the gene
machine from "running away," as often happens whe
resistance opposing its working is suddenly withdrawn.
have seen that Jablochkoff used a similar plan for re-ligh
his candles, and I am told his plan was patented a
before that of which we are speaking.

In order to keep the luminous point stationary in elec
candles, the Abbé Lavaud de l'Estrade has contrived a ki
of candlestick in which the candle is supported by a flo
For this purpose the candlestick has three vertical rods, t
of which terminate in cylindro-conical vessels plunged i
two tubes filled with mercury. The third rod serves a
guide, and a rack enables the mercury tubes to be placed
any suitable height. The object of the vessels is to keep
electric candle at any given height, and their capacity, as w
as the volume of the rods which they supported, are cal
lated accordingly. This height may, it is true, be modified
means of the rack, but the equilibrium between the wei
of the candle and the tendency of the vessels to rise up b
always the same, so long as the candle keeps its weight
vessels are immersed to the same extent, whatever ma
the position of the system supporting the candle. It is
when the candle comes to be consumed that this equilib
is destroyed and the candle rises, the amount being
mined by the relation between the volume of the carbo
sumed and that of a cylinder of mercury having a di
equal to that of the rods and the weight of the carbo
sumed. If the rods attached to the vessels have
diameter as that the weight of the mercury they
precisely corresponds with the weight of the carbon
and such that the height they project from the m
be exactly the same as that by which the carbon

ned by their combustion, the luminous point will remain t the same elevation, and the electric candle may thus be sed for projecting images on a screen like the electric lamp with clockwork movements. Lavaud de l'Estrade points out yet another arrangement for obtaining the same effects with Wilde's candle, but these apparatus are not yet sufficiently practical for us to dwell upon them.

Other systems of electric lights have been proposed, and we should never have done if we considered all the more or less fanciful ideas which have been advanced. To give a notion of their value, we need but allude to the method mentioned in certain newspapers, of covering the walls of rooms with fluorescent and phosphorescent substances, which, according to these projectors, will in the daytime store up light sufficing to illuminate the rooms by night. This simple notice will serve to show how far the imagination will run when it is not controlled by a wise theory.

At the exhibition of electric light in the Albert Hall, at London, in 1879, more than 25 different electric lamps were on view. There were, in the first place, specimens of all that we have described; and besides, there was a new form of incandescent lamp, contrived by Higgin, which was very similar to that of Ducretet, and in which use was made of mercury to push on the movable carbon in proportion to its rate of consumption.

PART IV.—COST OF ELECTRIC LIGHTIN

The expenses attending electric lighting are of vario kinds, and belong, independently of the first cost of t apparatus, to—1°, the production of the electric curre 2°, the combustion of the carbons. It is true that fo long time little attention was paid to this last expe because it was so small in comparison with the other. now when, thanks to induction machines and thermo-ele piles, electricity can be cheaply produced, it has become portant, and may reach a higher figure than the other, cially with electric candles.

At various times important investigations have been regarding the cost of the voltaic arc, either with batter with induction machines, and we are going to giv briefest possible summary of them, although it must b fessed that they are not yet sufficiently conclusive to l plicitly relied upon.

Cost of the Electric Light with Batteries.— interesting Report presented in 1856 to the *Societé d'enc ment*, Ed. Becquerel states that when applied to the I tion of a voltaic arc, a Bunsen battery of 60 elements, zincs 20 centimètres high by 8·5 centimetres diamet porous vessels 20 centimetres high by 6·5, consume hours 956 grammes of zinc and 1,464 grammes of su acid. This makes the cost about 1 franc per hour. Esti the expenditure of nitric acid at one equivalent of a one of zinc, as shown by experiment, Becquerel es the cost of that liquid at 1 franc 46 centimes, which give a total cost of 2 francs 46 centimes. But, as h out, the real cost is higher than that, for even if t that remains could be used for other purposes, the nit lowered from 36° to 25° of the hydrometer will no longer act with sufficient energy to yield the voltaic arc under advantageous conditions. It is also necessary to take into account the loss of mercury, the somewhat greater consumption of zinc than theory indicates, and the consumption of the carbons between which the arc passes, the value of which is 2 francs 50 centimes per lineal metre. "The cost per hour then amounts," says Becquerel, "to 3 francs for the 60 cells, or about 5 centimes per hour for each cell. However, the cost for a given luminous intensity is not the same at the beginning and at the end of an experiment; this results from the diminution in the electric intensity of the cells, that is to say, from the change in the composition of the liquids they contain. It is nevertheless one result which ought to be stated, as it facilitates the inquiry into the price of working a Bunsen battery; it is, that for every 1 franc's-worth of zinc the other materials may be estimated at 1fr. 50, so that the total cost cannot be less than 2fr. 50."

A curious remark made by Becquerel is that the luminous intensity diminishes much more rapidly than the intensity of the current, and this depends upon the fact that the luminous intensity, being a function of the quantity of heat disengaged, must, like it, vary as the square of the quantity of electricity which passes through the circuit in a given time, according to Joule's law. (See page 6.)

"We see," Becquerel concludes, "that according to the determinations I have given, having regard merely to the cost of the substances consumed, and without including labour, the electric light would, light for light, be four times dearer than gas-lighting at the selling price of gas in Paris. It would be the same as that of lighting by oil, and a quarter of that of lighting by andles. But if we estimate the labour required to superintend he apparatus, to get it ready, and to renew the batteries, &c., the ost would increase by at least half as much again the amount entioned above."

According to experiments made at Lyons during 100 hours by Lacassagne and Thi[illegible], for the lighting of the Rue Impérial, which required [illegible] battery of 60 Bunsen cells, the cost amounted to about [illegible] francs per hour for a light equivalent to a mean of 50 Carcel lamps (75 at the beginning, 30 at the end), and this cost was distributed as follows:

Substances	Consumed in 100 hours.	Price.	Total price.	Cost per hour.	Actual cost.
	Kilos.	Fr. per 100 kilos.	Fr.	Fr.	Fr. per 100 kilos.
Zinc	72·00	104	74·95	0·75	80
Sulphuric Acid	154·00	24	36·95	0·37	12
Nitric Acid ...	247·00	70	173·25	1·73	56
Mercury ...	9·00	550	49·75	0·50	650
Purified Carbon	6·61 metres	3 per metre	19·85	0·20	2·50 per metre
		Totals	354·75	3·55	

This cost of 3 fr. 55 c. per hour is nearly the same as that calculated by Becquerel from the actual expenditure.

According to new and very interesting investigations undertaken by Reynier, the cost of the electric light with incandescence lamps may be reckoned as follows for each Carcel lamp per hour:

	Fr. c.
With a Bunsen battery (Ruhmkorff's form) ...	0·122
„ a Thompson battery (large size)	0 062
„ a bichromate of potassium battery, with porous vessels, chloride of ammonium and mercury (Goarant and Tromelin's form)	0·180

In order to obtain a current equivalent to that from 8 Bunsen cells (Ruhmkorff's form), giving a light of from 6 to 12 Carcel lamps, 45 Thompson cells, or 24 Goarant and Tromelin cells, would be required.

It will be seen from these figures that the economical solution of the problem of electric lighting is not to be found in batteries with liquids.

The two actions which formerly combined now oppose other ; so far from lengthening the arc, they shorten it ; ad of lessening its resistance to rupture and diminishing the nsity of the current, they increase both.

'This arc may be said to be compressed between two opposite tions ; it is shorter, narrower, less expanded, denser, and con- quently hotter, and the number of the lights may be increased. he Jablochkoff candles, otherwise so well arranged, possess the iconvenience of having their points upwards. The arcs they rm naturally tend to curve and rise up, a tendency which is trengthened by the electro-magnetic action of the current scending in one carbon and descending in the other : an action lentical with that in my directive circuit, though smaller in mount. The burners with the points downwards should there- re surpass these candles, as, indeed, experience proves. With machine which is sufficient, with difficulty, to light three candles, easily supply five burners, fitted with much larger carbons, ich burner giving twice as much light as a candle ; and as the ints are immersed in the mass of the arc, they are more bril- hted, but they give a sum total of light less than five do ; the mber may be doubled, but there is a loss in the quantity of ht. It is always thus when we try to divide the electric light yond a certain extent ; the division is purchased by a propor- al loss.

It is interesting to examine the behaviour of these burners· en the points are upwards, the first lighting is very difficult, use the arc is at once briskly thrown upwards by the in- ce of the directive current, which is proportional to the re of the intensity. When this increases it becomes abso- impossible to light the carbons ; we get nothing but a great , which immediately disappears with a snap. If the current aker the light remains, but very diffused, very high, and s very noisy, on account of the oscillations which take place h inversion of the current. Again, the equilibrium is le ; if an accidental current of air for an instant raises the of the arc, it cannot be brought back ; the limit of its y is exceeded, and it immediately breaks. In the burners points downwards the lighting is easy and the equili- able, for if a movement of the air, or a failure, causes the

arc to rise, it is established between the
where they have not been worn away
up a position where the interval does e
So far from being lengthened, it is sh
being lessened, the resistance to rupture
current are increased, and the light is se
again, and resume its position at the ext
if, on the contrary, the current increases
comes concave towards the carbons, b
counterbalancing the action of the direc
sufficiently elongated to break. The bes
are obtained when this curve is just suff
vent the upward movement of the arc.
able noise of the electric light is reduced
the amplitudes of the vibratory moven
possible.

"In short, the burner I submit to the
downwards, realizes considerable advar
since it involves no mechanism, and nee
paration; 2°. mechanical economy, sinc
may be doubled; 3°. increase of light,
lamps has double the power of the old on
which is whiter; 5°. a better arrangeme
throw the greater part of their light
towards the sky, where it is useless; a
combustibles, since the consumption is
thickness of the carbons. All this form
the electric light, and cannot fail to stre
already taken on public illumination, tha
to Jablochkoff's candle, and to the progr

Jamin has quite recently added to
magnetic arrangement which, as in W
the candle to be automatically lightec
tinction. For this purpose he makes
multiplier that surrounds the candle,
the plate by which the system is supp
branches of a plate of iron bent into a
branches consequently constitute whi

two poles capable of attracting soft iron armatures. These armatures are provided with stops and with opposing springs, and are each attached to a jointed arm placed in a different direction, and connected on either side with one of the carbon-holders. Now it follows from this arrangement that each current sent out of the machine produces a double attraction, and gives rise to a movement that becomes vibratory by reason of the rapid succession of the currents, and this movement, by bringing the carbons nearer to and further from each other, keeps them continuously lighted. This movement may moreover be more or less marked by means of the stops and springs of the armature. (See, for details of this arrangement, the journal *La Nature* of the 20th September, 1879.)

The company which manufactures the De Mériten's machines now devotes some attention to fabricating carbons for the electric light, and candles of a new form invented by Soligniac, which, it seems, yield very good results. These candles have four carbons of unequal diameter, separated from each other by an interval of half a millimetre, are connected together in the same plane by two insulating and volatilizable bands. The two outside carbons have a larger diameter than the others (4 millimetres), which are only 2½ millimetres in diameter; the outside carbons are, moreover, fitted into copper sockets, by which the electric communication is made with the lamp. Finally, the four carbons are at their bases connected by plaster of Paris, which occupies all the space between the two sockets. It appears that candles on this plan can only work well with four carbons, and that those in which only three are used must be abandoned.

We have seen (p. 139) that Alkelmer sought to diminish the resistance of electric carbons by introducing metallic plates between the sides of the insulator and the carbons. Now these plates also possess, according to him, the very great advantage of enabling the candle to be automatically

re-lighted; but in that case it is nece
should be made of a moderately con
resistance of which is calculated acco
ment moreover enables the current
when the light goes out, and this p
machine from "running away," as o
resistance opposing its working is sud
have seen that Jablochkoff used a sim
his candles, and I am told his plan
before that of which we are speaking.

In order to keep the luminous poi
candles, the Abbé Lavaud de l'Estrad
of candlestick in which the candle is
For this purpose the candlestick has
of which terminate in cylindro-conic
two tubes filled with mercury. The
guide, and a rack enables the mercur
any suitable height. The object of th
electric candle at any given height, an
as the volume of the rods which the
lated accordingly. This height may, it
means of the rack, but the equilibriu
of the candle and the tendency of the
always the same, so long as the cand
vessels are immersed to the same e
the position of the system supporting
when the candle comes to be consum
is destroyed and the candle rises, th
mined by the relation between the vol
sumed and that of a cylinder of merc
equal to that of the rods and the wei
sumed. If the rods attached to th
diameter as that the weight of the
precisely corresponds with the weight o
and such that the height they project
be exactly the same as that by which

ened by their combustion, the luminous point will remain at the same elevation, and the electric candle may thus be used for projecting images on a screen like the electric lamp with clockwork movements. Lavaud de l'Estrade points out yet another arrangement for obtaining the same effects with Wilde's candle, but these apparatus are not yet sufficiently practical for us to dwell upon them.

Other systems of electric lights have been proposed, and we should never have done if we considered all the more or less fanciful ideas which have been advanced. To give a notion of their value, we need but allude to the method mentioned in certain newspapers, of covering the walls of rooms with fluorescent and phosphorescent substances, which, according to these projectors, will in the daytime store up light sufficing to illuminate the rooms by night. This simple notice will serve to show how far the imagination will run when it is not controlled by a wise theory.

At the exhibition of electric light in the Albert Hall, at London, in 1879, more than 25 different electric lamps were on view. There were, in the first place, specimens of all that we have described; and besides, there was a new form of incandescent lamp, contrived by Higgin, which was very similar to that of Ducretet, and in which use was made of mercury to push on the movable carbon in proportion to its rate of consumption.

ered from 36° to 25° of the hydrometer will no longer sufficient energy to yield the voltaic arc under [illegible] act ous conditions. It is also necessary to take into account the loss of mercury, the somewhat greater consumption [illegible] than theory indicates, and the consumption of the [illegible] between which the arc passes, the value of which [illegible] is ncs 50 centimes per lineal metre. "The cost per hour amounts," says Becquerel, "to 3 francs for the 60 cells, out 5 centimes per hour for each cell. However, the for a given luminous intensity is not the same at the be- ng and at the end of an experiment; this results from iminution in the electric intensity of the cells, that is to rom the change in the composition of the liquids they in. It is nevertheless one result which ought to be d, as it facilitates the inquiry into the price of work [illegible] nsen battery; it is, that for every 1 franc's-worth of zinc ther materials may be estimated at 1fr. 50, so that the cost cannot be less than 2fr. 50."

curious remark made by Becquerel is that the luminous sity diminishes much more rapidly than the intensity of urrent, and this depends upon the fact that the luminous sity, being a function of the quantity of heat disengaged, like it, vary as the square of the quantity of electricity passes through the circuit in a given time, according ule's law. (See page 6.)

"We see," Becquerel concludes, "that according to the de- tions I have given, having regard merely to the cost of the ances consumed, and without including labour, the electric would, light for light, be four times dearer than gas-light- the selling price of gas in Paris. It would be the same at of lighting by oil, and a quarter of that of lighting by es. But if we estimate the labour required to superintend pparatus, to get it ready, and to renew the batteries, &c., the would increase by at least half as much again the amount oned above."

cording to experiments made at Lyons during 100 hours

In ord
8 Bunsen
6 to 12 C
and Trome
It will b
solution of
found in h

by Lacassagne and Thiers, for the lighting of the Rue Impe rial, which required a battery of 60 Bunsen cells, the cost amounted to about 3 francs per hour for a light equivalent to a mean of 50 Carcel lamps (75 at the beginning, 30 at the end), and this cost was distributed as follows:

Substances	Consumed in 100 hours.	Price.	Total price.	Cost per hour.	Actual cost.
	Kilos.	Fr. per 100 kilos.	Fr.	Fr.	Fr. per 100 kilos.
Zinc	72·00	104	74·95	0·75	80
Sulphuric Acid	154·00	24	36·95	0·37	12
Nitric Acid ...	247·00	70	173·25	1·73	56
Mercury ...	9·00	550	49·75	0·50	650
Purified Carbon	6·61 metres	3 per metre	19·85	0·20	2·50 per me
Totals	..	...	354·75	3·55	

This cost of 3 fr. 55 c. per hour is nearly the same as t calculated by Becquerel from the actual expenditure.

According to new and very interesting investigations un taken by Reynier, the cost of the electric light with inc descence lamps may be reckoned as follows for each Ca lamp per hour:

With a Bunsen battery (Ruhmkorff's form) ...	Fr. 0·12
„ a Thompson battery (large size)	0·06
„ a bichromate of potassium battery, with porous vessels, chloride of ammonium and mercury (Goarant and Tromelin's form)	0·18

In order to obtain a current equivalent to that f 8 Bunsen cells (Ruhmkorff's form), giving a light of 6 to 12 Carcel lamps, 45 Thompson cells, or 24 Go and Tromelin cells, would be required.

It will be seen from these figures that the econ solution of the problem of electric lighting is not found in batteries with liquids.

Cost of the Electric Light with Induction Machines.—We have seen that according to the experiments of Jamin and Roger the electro-motive force of the current from an *Alliance* magneto-electric machine with 6 discs, having the bobbins arranged for tension and with a speed of 200 rotations per minute, is equivalent to that of 226 Bunsen cells; but when the bobbins are arranged for quantity, it is equivalent to the current from only 38 Bunsen cells. We have also seen that the resistance of the generator should be considered fictitiously with regard to Ohm's law as being equivalent to that of 665 Bunsen cells in the first case, and to that of 18 cells in the second case. The light produced by that machine was, with the earlier arrangements of it for lighthouses, equal to 230 Carcel lamps; and according to the calculations of Reynaud, Inspector of Lighthouses, the cost of the current was 1 franc 10 centimes per hour.* If this cost is compared with that of the current from a Bunsen battery of the same power, calculated from the data given by E. Becquerel, the economy of using these machines is in the proportion of 1 franc 10 centimes to 11 francs 30 centimes, that is to say, more than tenfold; and the cost of the light, compared to that given by ordinary oil in a Carcel lamp, would be only one-seventh. We must, however, observe that the carbons have not been taken into account.

According to Le Roux's experiments, the cost of the electric light produced by the *Alliance* machines would,

---

* The cost was distributed as follows:—

	Francs.
Interest of capital expended in the purchase of the machines	0·28
Fuel for steam engine	0·40
Engineer's wages	0·35
Lubrication, &c.	0·07
	1·10

Complete data on this question will be found in the Report of Le Roux (*Bulletin de les Société d'Encouragement, tome XIV*, page 776), and in Reynaud's Paper on the lighthouses and beacons of the French coast (*Paris Imprimerie Nationale*, 1864).

"These figures are deduced from practice, and we have never found that they are too favourable: on the contrary, it has in many cases been observed that the cost per Carcel lamp is less than that we have named."

According to the tables given in Fontaine's work, pages 200 and 201, it appears that for the same luminous intensity, the Gramme machine, under the most unfavourable circumstances, would produce a light

75 times cheaper than that of wax candles.			
55	"	"	stearine candles.
16	"	"	colza oil.
11	"	"	gas at 30 centimes per cubic metre.
6½	"	"	gas at 15 centimes per cubic metre.

Under the most favourable conditions this light would be

300 times cheaper than that of wax candles.			
200	"	"	stearine candles.
65	"	"	colza oil.
40	"	"	gas at 30 centimes per cubic metre.
22	"	"	gas at 15 centimes per cubic metre.

The economy in the cost of lighting by fitting up a spinning-mill of 800 looms with Gramme machines, instead of fitting it up with gas, is found to be 33 per cent., and this with six times as much light supplied.

From an interesting notice just published by R. V. Picou, engineer of arts and manufactures, we extract the following particulars, which appear free from all exaggeration in either direction, and which indicate the price [illegible] of a franc as representing the expense of an electric lamp per hour, supplied by a[illegible] ordi-

According to Picou, an electric lamp [illegible] from nary Gramme machine would be able [illegible] 250 to 500 square metres of a workshop [illegible] operations are carried on; 500 to 1,000 square [illegible] machine-fitting shops, and 2,000 square [illegible] yard.

The expense of fitting-up would be

COST OF ELECTRIC LIGH

Gramme machine
Serrin lamp ...
Accessories of the above ... ...
Conducting wires ... ...
Transmission ... ...
Carriage and packing ... ...
Various ... ...
Total

and the working expenses per hour woul

Retort carbon
Coke for motive power ... ...
Working expenses and management ... ...
Sinking of 2,300 fr., divided over 500 h
of lighting yearly ... ...
Total ...

If lighted throughout every night, th
hours in a year, the cost falls to 53 centi

With an hydraulic motor the expenses
an illumination of 500 hours, and 38 cen
nation of 4,000 hours.

A workshop of 60 metres by 20 will
which will entail a cost of 1 fr. 77 c.
3 fr. 50 c., the expense of 100 gas-lights
be used in such a case, and which woul
or one-sixth of the total intensity of ligh

If the workshop is open all the nigh
becomes 0 fr. 97 c. with the electric light,
gas.

It will be interesting to compare these
results that were published in England aft
experiments, and we give an abstract o
read before the Society of Civil Engin
Higgs and Brittle, entitled *"On some re
Dynamo-electric Apparatus."*

"Although under certain circumstances these two agents undoubtedly come into competition, they have two separate fields. Hitherto gas been generally employed for lighting spaces of both large and small dimensions, because a better source of light for large spaces has not been procurable with economy. But for lighting large spaces that are not subdivided by opaque objects or screens, it is a want of economy to employ gas. If, in fact, a gasworks were to be constructed simply for lighting large spaces, as does occur in some extensive works, the disbursement necessary to establish even a small gasworks would, compared with that necessary to establish the electric light, be a considerable multiple of the latter. Assuming light-power proportional to horse-power expended (although it increases at a greater rate), 100 horse-power would give 150,000 candles light; if this be distributed from three points, the cost of each lamp per hour would not be more than 7*s.* 6*d.*, or £1 2*s.* 6*d.* per hour for the three, each light centre giving an illumination which would enable small print to be read at a distance of a ¼ mile from the light. A burner giving the light of 20 candles consumes 6 cubic feet of gas per hour, which may be manufactured at a cost of 2*s.* per 1,000 cubic feet. This gives 7,500 burners' light only, and 45,000 cubic feet of gas at a cost of £4 10*s.* per hour, a ratio of 4 to 1 in favour of electric lighting. Electric lighting, where adopted, has been found to be generally more economical than gas lighting, but the economical ratios differ greatly, and are dependent chiefly upon the price of gas and the motor power employed. For large spaces the cost of electric lighting is about one-fourth, or even one-fifth of that of gas lighting, when steam has been used as a power, and wear and tear are reckoned. With a gas engine as motor, the ratio has only been as 1 to 3, the greatest economy having been with a turbine as motor. At Dieu's workshops at Davours the cost per hour for gas is 2*s.* 0 632*d.* against 1*s.* 7.2*d.* for electric lighting. Ducommun finds, taking into account wear and tear and interest, that gas costs 2·25 times more than the electric light, which ratio increases to 7·15 when wear and tear and interest are left out of consideration. At Siemens Brothers' Telegraph Works the cable shops are imperfectly lighted with 120 gas-burners. Each of these burners consumes 6 cubic feet per hour, at a cost of 3*s.* 9*d.* per 1,000 cubic feet. The cost of fixing gas-pipes, including cost of pipes, "The objection that the glare of the electric light is trying to the eyes of the workpeople, has been overcome by inclosing the light in an opaque reflector, the rays being projected on to a screen, or on to the ceiling or roof of the building, whence they are diffused, giving to the space lighted the appearance of illumination by daylight."

antage over lights dispersed in a number of different nts. This truth was established a score of years ago, by the eriments in the *Place du Carrousel*, not indeed with the tric light, but with a light equally intense, which formed the tre of a splendidly luminous sphere. It was finally admitted this single point was far from supplying the same advan- s as ordinary gas-jets, which could be placed as required. y, if we remember that the special characteristic of the tric light is its concentrated power, we may conclude if this light had to remain subjected to the same condi- s under which it existed a few years ago, it would never been regarded as a mode of public illumination. Never- ess, the considerable reduction of the cost of this light, the methods of dividing it under favourable conditions, h have recently been discovered, have changed the aspect ne question. The important experiments undertaken in 8 by the Jablochkoff Company gave rise to new ideas, h have now been taken up by all civilized countries, and nise to lead to some important results. It is therefore surprising that the gas companies should have been ted, and their shares depreciated. Nevertheless we the depreciation has been unduly exaggerated, for, as emarked at the beginning, it is difficult to believe that will not be found for gas, considering the important pur- s to which it can be applied in very many branches of stry.

e have already explained the manner in which the ric light can be divided sufficiently for the requirements ublic illumination, by means of induction machines with coils, Jablochkoff candles, the lamps of Lontin, Rey- Werdermann, &c. We must not, however, suppose that idea is new. The division of the electric light has long sought after, and several plans have been proposed, as those of Wartmann, Quirini, Liais, Deleuil, Ronalds, ssagne and Thiers, and Martin de Brettes, which I described in my *Exposé des applications de l'électricité*,

---

anc
225.
from the
a commut
machines
cellars und
are divided
bundles go
down. Th
ments

and tarred canvas, they are protected by well-fitted drain-pipes. There are openings in front of each lamp-post and in these are made the connections between the wires of each lamp and those of the circuit. Of course the seven wires are only between the commutator and the candles; everywhere else there are only two for each set of four lamps.

It appears that the two machines require 36 horse-power in order to light 32 lamps on each side of the street, that is, every lamp requires 1·12 H.P.; but it should be noticed that in this estimate the power needed to overcome the resistance of the conductors is included, and that this must be considerable is obvious from the fact that for the most distant conductors it is nearly 1,000 metres of wire.

Jablochkoff asserts that each of the lamps represents from 25 to 30 gas-jets; but F. Leblanc declares that it does not exceed 12 jets, and it is on this estimate that the last contract between the Jablochkoff Company and the city of Paris is based. We must, however, bear in mind that nearly 45 per cent. of the light is absorbed by the enamelled glass globes; so that it is possible that each light represents 50 or 60 Carcel lamps according to Jablochkoff, or 22 to 24 such lamps according to Leblanc. According to the original agreement between the city of Paris and the Jablochkoff Company, the cost to the city was six times that of gas. It is now much reduced, and unless the company is a loser by the new agreement it has entered into with the city of Paris, the cost may be said to be nearly that of gas, for it is only one-fourth as much as under the first agreement.

The debates in the Municipal Council on the renewal of their agreement may illustrate the cost of maintaining this system of lighting. The illumination of the *Avenue de l'Opéra*, together with that of the *Place de l'Opéra*, the *Place du Théâtre Français*, and the façade of the *Corps Législatif*, originally cost 1 franc 25 centimes for each lamp per hour. Now according to Mallet, 68 gas-jets may be had for this sum, and thus electric lighting would be at a disadvantage in the proportion of 1 to 6. But the amount of 1·25 francs was in the last discussion in the Council reduced to 30 centimes, which it seems the Jablochkoff Company have accepted, as the lighting is continued. We think, however, that under these conditions the company must be out of pocket, for according to the calculations of the Reporter to the Municipal Council the cost must amount to 75 centimes.

As the subject is interesting on account of the difficulty of obtaining exact *data*, it may be useful to give a summary of what was said on this subject in the Municipal Council.

According to the Report of Cernesson, the cost of maintenance for each electric lamp per hour may be deduced from the following list of the expenses of lighting 62 lamps for the space of one hour:—

	Fr. c.
Motive power (sundry expenses)	3·20
Fuel (for the engines)	6·64
Oil for lubrication	1·23
Wages of attendant	3·20
62 candles at 50 centimes each	31·00
Total ...	45·27

This gives for each candle 0 fr. 75 cent. Yet the Company were content to demand only 0 fr. 60 cent., and wished the Council to enter into an agreement on those terms: the Report did not, however, recommend a compliance with this, but established the principle of paying the Company in proportion to the amount of light supplied.

> "Each of the electric lamps," says the Report, "having been supposed to give as much light as 11 gas-jets consuming 140 litres per hour, and costing each about 2½ centimes, the Commission considers that a sum of 30 centimes per lamp per hour should be allotted to the Company. According to the preceding scale the Company would be entitled to only 27 centimes."

As to the Electric Lighting Company's project of undertaking for three years the illumination of the principal thoroughfares of Paris, the Commission distinctly refused to bind itself in any particular way, but decided that in the present condition of affairs, electricity, as represented by the Jablochkoff candle, could not be considered as having reached such a degree of perfection that it could supersede gas; that, nevertheless, the progress that had been effected was sufficiently real and important to justify a continuance of the experiments on a larger scale. The Commission therefore considers that the *Avenue de l'Opéra* should continue to be lighted as before for one year, beginning on the 15th January, and that the Company might apply its system in two new positions in the city of Paris, viz., the *Place de la Bastille* and one of the wings of the central markets. (See the journal *L'Électricité* of the 5th and 20th January.)

The illumination of the *Avenue de l'Opéra* and of the *Place du Théâtre-Français* allows but one candle to each lamp, and there are in all forty-eight luminous points. On the *Place de l'Opéra* there are only eight lamps, but two candles burn together in each of them; the two triple lamps placed on each side of the façade of the Opera-House have simple candles only. These two lamps are supplied by two *Alliance* machines, but those in the *Place de l'Opéra* are worked by a Gramme dividing machine, and this requires for the electric lighting of this part of Paris the employment of four machines, each using from sixteen to eighteen horse-power. The *Place de la Bastille* and the central market are each lighted by sixteen lamps.

In spite of the fierce hostility with which the gas companies attacked the newspapers in these trials of electric lighting, every civilized country is now turning its attention to this subject. The cities of Stockholm, St. Petersburg, Amsterdam, and San Francisco have already taken steps to establish the electric light. The City of London is at present engaged in realizing this application of electricity, and the Thames Embankment is now lighted in this way. Even America has made repeated attempts to reach an immediate solution of the problem. Shall we have merely courage to adopt this beautiful application of scien after it has been carried into effect by every other as in the cases of the electric telegraph, railways, &c.? would be hard, after having made the first experiments

We have hitherto discussed only the light given b Jablochkoff candles; but this system is not the onl which may be employed for public illumination, and perhaps, not even the most economical for the ligh duced. The globes of enamelled glass are, for one th bad arrangement, as they prevent the utilization of th light, and the Baccarat frosted glass, which allows 70 pe of the light to pass instead of 55, have been tried, as w seen, with much advantage. Again, there is now bein Páris's new kind of enamelled glass, which absorbs o per cent. of the light, and Clémandot's globes, f of concentric spheres of transparent glass, with a pack glass between them. This arrangement, when tried at of the *Louvre*, absorbed, it is said, only 24 per cent. light instead of 45. With the Reynier and Wed systems, applied to the existing lamps, a greater div the light, and probably a smaller consumption of the c would be obtained, with equal electric intensity. If th bons were placed within the column of the lamp, whic easily be done in the Wedermann arrangement, they burn a whole night without requiring attention. Agai new machines it would be possible to reduce in such a the expenditure of motive power that the high price electric light, which under the present conditions strong point of the partizans of gas, may be suffic lowered to compete successfully with gas itself. For li on the spot, the problem has, as we have seen, been lon completely solved; and it is not affirmed that by incr the section of the conductors, and expending upon th much as the cost of gas-pipes, public illumination woul be placed under conditions of economy as favourable a light were near the machine. We therefore see no reason why the cost of electric lighting should not come to be lower than that of gas lighting. It is only a question of time, and the important point was to prove that public illumination by electricity was not physically impossible — a matter upon which we now know what opinion to hold.

It has been asserted that the electric light was hurtful to the eye, disagreeable in its effect, and alarming to horses. The experiments of the last six months have not given me any such impression; and if we stand in the evening at the corner of the *Rue de la Paix* and the *Avenue de l'Opéra*, and compare the ilumination of the two thoroughfares, especially as regards the houses on either side, we should suppose that one of the streets is dark. Certainly, when the electric lighting of the *Avenue de l'Opéra* is given up, the public will find a vast difference, and will not easily become accustomed to the gas-lamps, which serve only to make the darkness visible; and yet these lamps contain three gas-jets where a little while ago there was only one.

As to the bluish hue of the electric light, it looks cold only because we are accustomed to reddish lights; but if a red tint were required, it would not be difficult to impart it, by introducing certain colouring salts into the composition of the carbons. It is, however, difficult to suppose that this objection is seriously advanced; for it seems to me that a white light, resembling that of the sun and showing colours in their proper hues, is preferable to one which casts a false tint on all objects. Those who find fault with the electric light on this ground must equally object to those beautiful moonlight effects that are so much praised by artists and poets.

In the pamphlet published by the Jablochkoff Company the advantages of electricity for public lighting are thus set forth :—

"Besides the economy of the light it has the following qualities :—

"1°. It does not alter colours, but allows the closest tints to be distinguished, which would be impossible with gaslight. In every industry where the qualities of objects have to be judged of from their colour, in those where there are sortings or selections according to tints, in assorting stuffs or thread of various shades, the electric light is of unquestioned utility.

"2°. The heat given off by electric lighting is extremely small. It is well known at what trouble and cost a very imperfect ventilation of apartments in which a number of gas-jets are burnt can be obtained.

"3°. In industrial establishments the electric light supplies a general illumination, which facilitates superintendence at the same time that it simplifies all work of transport, management, &c., &c. It enables, therefore, the number of workmen employed in night shifts to be diminished, and consequently the extent of the premises in which the work is carried on to be reduced. There is thus, together with less cost, an economy of labour and an economy of the prime cost of the establishment.

"4°. It removes the danger of using gas, which results either from negligence or from an escape from the pipes, as when the turning of a tap is forgotten or the pipes are fused in a fire otherwise originating.

"Nothing of this kind happens when the electric light is used. Instead of the fusible lead-piping, from which the gas can so readily be allowed to escape, and which can so easily be maliciously injured, the electric communication is by a cord or copper wire covered with an insulating substance. If the circuit were cut, which could only happen intentionally, the reverse would take place from what occurs in the case of gas, for the fluid would no longer flow, and the light would be extinguished. So that, while in the one case the gas from a leakage very easily occasioned, either by accident or by malice, spreads rapidly and forms with the air a mixture that a spark would cause to explode; in the other case, if the circuit is interrupted there is merely a simple extinction of the lights.

"Fires may also be occasioned by the direct action of the gas-jets on combustible materials. Now, an electric lamp having a flame of scarcely any size takes the place of a great number of gas-jets, and the chances of a fire are proportionately reduced. It is, moreover, important to observe that as the combustion of gas gives off much heat, the inflammation of combustible materials is facilitated by the high temperature of places lighted by gas.

"The electric light, on the contrary, gives off extremely little heat, since a lamp yielding a light equal to that of several hundred stearine candles does not give more heat than a single candle.

"5°. All the lamps supplied by the same dynamo-electric machine are lighted up instantaneously."

When only a portion of the space has to be lighted in a given direction, and under an angle not exceeding 180 degrees, the diffusion projectors invented by J. Van Malderen may be used with advantage. These consist of a kind of parabolic mirror, of which the electric light occupies the centre, and with the front part closed at a short distance from the arc by a ground glass which receives the beam of parallel rays sent out by the mirror, spreads them out so that all the space in front is illuminated. It is stated that the intensity of the illumination is greatly increased in this way.

I think it will be interesting here to reproduce a letter by Lontin relating to the divisibility of the electric light, which has lately been so much spoken of, and has been put forward as a new discovery, the anterior labours of Wartmann, Quirini, and others being ignored. The letter was addressed to the journal *L'Électricité*, and appeared in the number for 5th November, 1878:—

"Allow me to remind you that two years ago I took out a patent for photo-electric regulators, which divide perfectly the current supplied to them.

"The *Alliance* electro-magnetic machine which was working in the Exhibition, supplied, it is true, 4 Jablochkoff candles, but this same machine, without any change, has worked 12 of my regulators. Here, I think, we truly have the divisibility of the electric light, a divisibility the more real since each of my regulators gave a luminous intensity of 19 Carcel lamps. This luminous power may, moreover, be yet further reduced, for I have obtained intensities of only 4 Carcels. I think I may conclude from these experiments that the *Alliance* machine, or one of my dynamo-electric machines suitably arranged for that purpose, can supply 50 regulators.

"The illumination of the Lyons railway station last year was supplied by one of my electric generators yielding 12 currents, each current maintaining 2 or 3 lamps. The new apparatus I am now fitting up will allow of 4 lamps being inserted in each current.

"At the Saint-Lazare station each current supplies 2 or 4 lamps, the intensity of which is regulated according to the requirements of the service."

Application to the Illumination of Lighthouses.—We are now no longer in the region of hypotheses, the application of the electric light to lighthouses being a *fait accompli* for more than fifteen years (1864), and I am not aware that any serious accident has interrupted the experiments. Most of the important lighthouses on the coasts of France, Russia, and England are thus lighted; and it is to the bold enterprise of the *Alliance* Company and its intelligent director, Berlioz, that the civilized world owes this beautiful application, which has certainly prevented many maritime disasters. It is true that Berlioz has been energetically assisted in his experiments by the Lighthouse Administration, and among others by Reynard and Degrand, who, after many intelligent experiments, arranged the lighthouses of La Hève on this new system towards the end of 1863. Some time afterwards England imitated us, and employed the electro-magnetic machines of Holmes, which were merely an inferior copy of those of the *Alliance.* Le Roux has published in the *Bulletin de la Société d'Encouragement* a very interesting paper on this kind of application, and we should have had great pleasure in reproducing it here had space permitted, but we shall give merely a summary of it, referring the reader to *tome XIV.* of the *Bulletin de la Société,* p. 762.

At the present time, dynamo-electric machines appear to be preferred, and the *Telegraphic Journal* in the number of the 1st December, 1877, gives many details of the manner in which the apparatus is fitted up in the lighthouses at Lizard Point. This would be very interesting to describe, but for want of space we shall at present content ourselves with considering the way in which the electric light is arranged at the top of the lighthouses.

The illuminating part of a lighthouse is constructed, as shown in Fig. 68, of a glass lantern formed of a certain number of Fresnel's *lentilles-à-échelons* (lenses in steps), in the centre of which the luminous focus is situated. This lantern is turned by powerful clockwork, and it is the passage of the separating zones between the different lentricular parts that produces those eclipses by which the light of a lighthouse is distinguished from that of an ordinary fire. The smaller the luminous point the more the effect is magnified by the lenses, and in order that the light shall be visible from a great distance it is essential that the luminous focus should be as bright and as small as possible. Now, the electric light solves this double problem, and therefore it appears expressly made for lighthouses. Nevertheless, as the electric light regulators are occasionally liable to extinction, and a prolonged extinction might cause serious disasters, the regulators (generally Serrin's or Siemens') are arranged in duplicate. They slide into the lantern on small rails placed on the surface of a cast-iron table, a stop arrests them when at the focus o the lenses, where they instantly light themselves, and thi is one of the great advantages of the electric light, espe cially with the regulators to which we refer. The electric communication is established on one hand by means of th cast-iron table, and on the other by a metallic spring whi presses against the upper part of the lamp at a convenien point. The substitution of one lamp for another does no equire more than two seconds, the one which is withdraw assing out by one of the railways whilst its substit nters by the other. The light may also be made to nstantly from one apparatus to the other by m

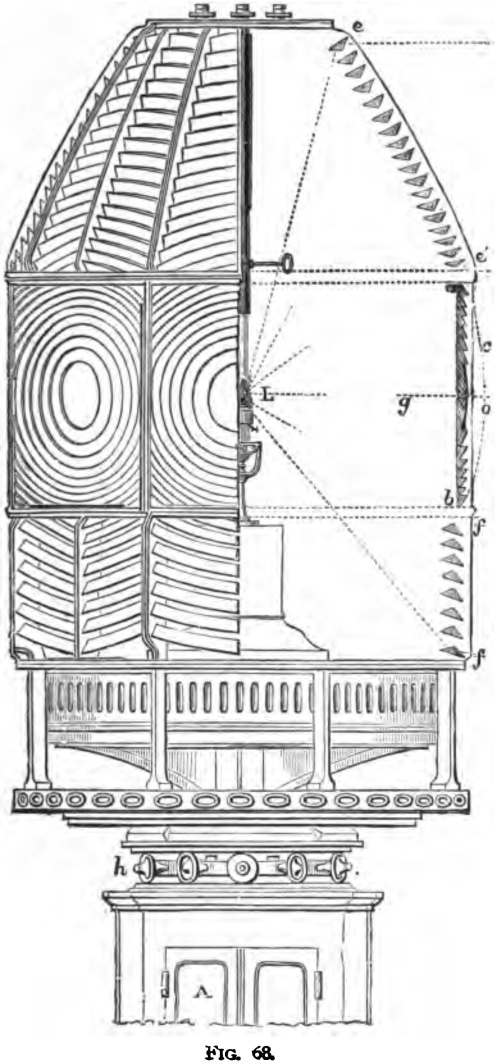


FIG. 68.

commutator, but to centralize the two points of light is a more difficult matter.

The carbons used in lighthouses are 7 millimetres wide and 27 centimetres long, and their rate of consumption is estimated at 5 centimetres per hour at each pole, at least with machines giving alternating currents. In spite of this uniform consumption there is, however, a slight difference, and the upper carbon is consumed a little faster than the lower, in the ratio of 108 to 100. The regulators are therefore very well adjusted, but as it is important that the variation of the luminous point shall be under 8 millimetres, without which the rays will not be sent out to the horizon, it is necessary to carefully attend to this light. In order that the keepers may be able easily to observe the progress of the carbons, an image of them is projected on the wall by means of a lens of short focus, a horizontal line is marked on the wall, and the points must be equally distant from that line. As a deviation of 1 millimetre is represented by a deviation of 22 millimetres on the wall, defects in the adjustment are readily seen.

This apparatus began to work at the lighthouse on the south cape of La Hève on the 26th December, 1863, and after fifteen months of experiments it was decided to apply the same plan of lighting to the second lighthouse. From that time electric lighting was definitely established.

As to the machines, which, like regulators, are provided in duplicate, they are generally placed in the base of the lighthouse tower, with the steam-engines for driving them, and well-insulated cables of a large diameter convey the current to the regulators, as we have already said.

According to Le Roux, it seems that even with the *Alliance* machines of 4 discs, the cost of the light is, on the average, one-seventh of that of oil.

In the natural state of the atmosphere the *Alliance* machines with 4 discs give a light visible at 38 kilometres, and those with 6 discs have a range of 50 kilometres; but it is curious that in foggy weather the electric light does not carry farther than that of oil lamps.

There are now several electric lighthouses in France, England, Russia, Austria, Sweden, and even in Egypt. Their working is everywhere satisfactory.

Application to the Lighting of Ships.—One of the most important applications of the electric light is for lighting ships in their course so as to avoid fouling, and show the entrances to ports in the night. The earliest attempts were made with the magneto-electric machines of the *Alliance* Company, and although the results were not entirely satisfactory, they were sufficiently successful to show that a solution of the problem would be effected in the immediate future.* The inconveniences for which the plan was blamed may thus be summed up:—The electric light produces round it a whitish cloud, fatiguing to the eye and injurious to observations; the fixed electric light, by its great intensity, obliterates the regulation green and red lights, which is a source of real danger; near the shore, ships might mistake the electric lantern for a lighthouse, and take a false course; finally, the apparatus is cumbersome, and the cost of fitting it up too great for the service it renders.

The greater part of these objections have lately been removed, by raising the luminous lantern to a certain height, by making the light intermittent, and by using the Gramme machines, which occupy a small space and are not costly. It was on board the transatlantic steamer *L'Amérique*, and under the direction of Captain Pouzolz, that this new system was first established; and it appears to have succeeded perfectly.

---

* The first attempts of the *Alliance* Company, at that time directed by Berlioz, were made as early as 1855, on board the *Jerome-Napoléon*, whose commander, M. Georgette Dubuisson, was a strong supporter of the system. They were afterwards repeated on board the *Saint-Laurent*, the *Forfait*, the *d'Estrée*, the *Héroine*, the *Coligny*, the *France;* and it may be seen by the Reports in *Les Mondes, tome XVIII., pp.* 51, 325, 458, 593, 637*; tome XVI., pp.* 488, 594*; tome XIII., pp.* 177, 405, 423*; tome VIII., p.* 592, that if the naval service in general attached little importance to this application, several distinguished officers fully appreciated its value. At that period, it is true, the electric lighthouses that have given such good results on board the *Amérique* had not been fitted up on ships, but an electric light lantern, very ingeniously arranged, was fixed on the mizzen-mast, and thus removed one of the principal objections that had been made.

Fontaine gives the following details on this subject:—

"The lantern is placed in the upper part of a turret ascended by internal steps, so it is not necessary to go on the bridge, for this turret rises above one of the companion-ladders. This arrangement is very advantageous, especially during heavy weather, when the bow is with difficulty accessible from the bridge. The turret was at first 7 metres high, but Pouzolz had it lowered by 2 metres to increase its stability, and to lower the level of the luminous beam; so that this turret is now 5 metres above the bridge. Its diameter is 1 metre, and it is placed in the fore part of the steamer at 15 metres from the stern.

"The lantern properly so called has prismatic glasses; it is able to illuminate an arc of 225° while leaving the steamer almost entirely in shade. The regulator, which is on Serrin's plan, is hung to the *cardan*. A small seat in the upper part of the tower allows the attendant to regulate the lamp. The luminous beam is about 8 diameters wide.

"The Gramme machine which supplies the luminous arc has a power of 200 Carcel lamps, and is driven by a motor on the Brotherhood system, which reduces the space occupied by the two to 1·20 metres by 0·60. These two machines are placed on a false floor in the engine-room, 40 metres from the lantern.

"All the wires pass through the captain's cabin, who has under his control commutators by which he can at will turn the light on or off in each of the two lamps without stopping the Gramme machine.

"The novelty of the arrangements on L'Amérique consists in the automatic intermittance of the light in the lantern. This intermittance is given by a very simple commutator attached to the end of the axle of the Gramme machine, which has the effect of alternately sending the current into the lamp, and into a closed metallic bundle of the same resistance as the voltaic arc, which bundle is heated and cooled alternately. This arrangement was adopted in order to keep the Gramme machine, which makes

850 revolutions per minute under always the same conditions as regards the external circuit. According to Pouzolz's calculations, the best relation between the eclipses and appearances of the light would be a light of 20 seconds and an eclipse of 100 seconds.

"The height of the luminous focus is 10 metres above the water, and the possible range of the light, in consequence of the depression of the horizon, is 10 marine miles (18,520 metres) for an observer with his eye at 6 metres above the water.

"In order to light up the topsails and the gallant-sails while the low sails are left in obscurity, Pouzolz had made a frustum of a cone in tin-plate, and placed it in the movable lamp, with the large opening outwards. In this way the *Amérique* was visible at a great distance from ships and signal-stations when the captain allowed the electric light to continue in action during the whole night."

It will be seen by this description that all the objections offered to the use of the electric light on ship-board have been removed by this new arrangement, and Pouzolz answers those which have been made to the use of an intermittent light by stating that the light produced by short flashes has never incommoded the sight of any officer of the watch or look-out man at the cathead, and that the brilliancy of the green and red side-lights is not at all diminished by the use of the lighthouse in front.

Since the dreadful collisions which have taken place within the last four years, there is now more inclination to resort to the electric light for ships; and we see that, according to Fontaine's book, in 1877, a certain number of Gramme machines have been set up on board several French, Danish, Russian, English, and Spanish ships of war, among which we may mention the *Livadia* and the *Peter the Great* of the Russian navy, the *Richelieu* and the *Suffren* of the French navy, and the *Rumancia* and the *Victoria* of the Spanish navy. It remains to describe the projecting apparatus, which, on account of the small space over which the light is to be thrown, is different from the lenticular apparatus of lighthouses. This apparatus is not essentially different from that which was put up on board of the *Jérôme Napoléon.* This

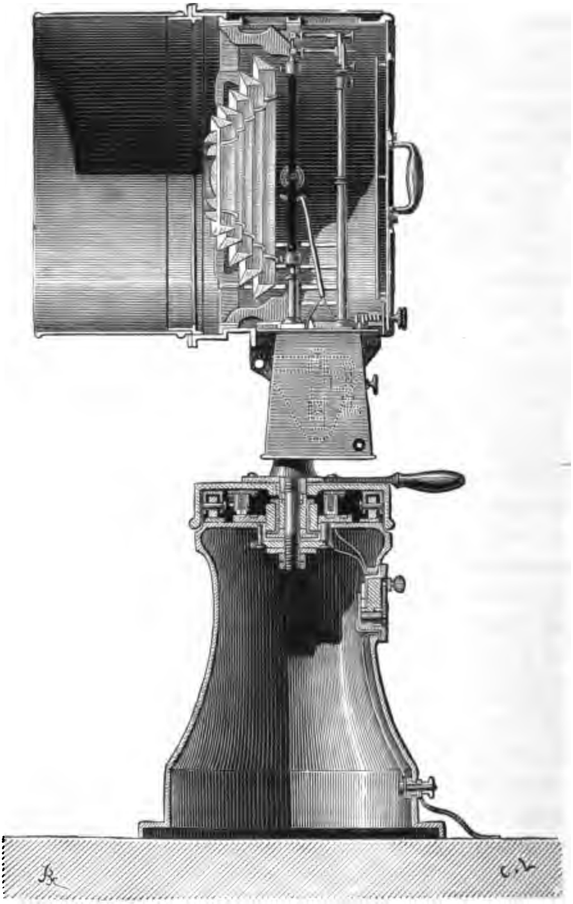


Fig. 69.

consisted of a parabolic reflector, in the focus of which was the voltaic arc produced by a Serrin regulator. This reflector, a little prolonged in front, was closed by a Fresnel lens, in order to transform the divergent beam into a parallel one. Finally, behind the regulator and the reflector was a small spherical reflector. The whole was mounted in a chamber movable on a pivot which, by a lever and rotating platform, permitted the beam to be sent in any direction. Further, a marine telescope fitted to the apparatus enabled the points of the horizon lighted by the beam to be observed. By placing in front of this beam coloured glasses, the light could be coloured green or red, and thus made suitable for marine signalling.

In Sautter and Lemonnier's projector, represented in Fig. 69, the spherical and parabolic reflectors do not exist, and the whole consists of a Fresnel lens composed of 3 droptric and 6 catadroptric elements. This lens is enclosed in a wide cylindrical tube, which, being supported on a pivot with the whole electrical arrangement, can be turned in any desired direction.

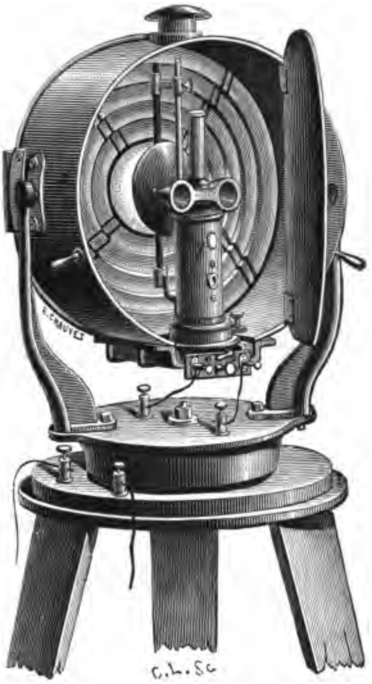


FIG. 70.

In Siemens' projector, represented in Fig. 70, the parabolic reflector is placed behind the lamp; and the latter is also provided with two lenticular arrangements for projecting the image of the carbons on a screen, thus facilitating their adjustment.

Application to Nautical Signals at long range.—Nocturnal signals exchanged between the various ships of a squadron are often inefficient on account of the feebleness of the light, and it would be desirable to make them clearer and visible at a greater distance. To accomplish this, De Mersanne arranged a particular system of regulator, which could not only be controlled at a distance, but was also regulated without requiring the presence of an attendant near the instrument.

This regulator has its carbon-holders mounted on two vertical rods provided with a screw movement, and capable of turning round on their own axes by an electro-magnetic mechanism controlled by a commutator. The apparatus is enclosed in a large lantern provided in its central part with a cylindrical system of "lenses-in-steps," at the focus of which the luminous arc is placed, and which is so arranged as to direct the light according to the height which the beam has to reach. Now it is in order to always keep the luminous point in the right place that the above-mentioned electro-mechanism is applied. This is composed of two straight and two horse-shoe electro-magnets, arranged in two perpendicular lines in a vertical plane. In the centre of these four electro-magnets there is on a forked armature a lever provided with a steel tooth, which passes between two parallel ratchets inversely disposed to the lower end of the two rods of the carbon-holders. When no current is passing in the electro-magnets the tooth is exactly between the two ratchet-wheels; but if, by means of the commutator, the current is passed through one of the straight electro-magnets—the upper one, for example—the lever already mentioned is raised, and the tooth at the end enters between two teeth of the upper ratchet-wheels, without, however, producing any effect; and it is only when the current is made to pass through the right electro-magnet that the latter causes the lever to turn, and pushes the tooth by one notch. The screw rod of the regulator then turns, by an amount proportionate to the escapement of this tooth, and lowers the corresponding carbon-holder. If now the lower straight electro-magnet be excited, the tooth of the lever engages the lower ratchet-wheel of the rod, and when the current is sent through the left electro-magnet the rod in question turns by the space of a tooth of the ratchet-wheel, but in the direction opposite to the former movement; and this causes the carbon to be raised that before was lowered. As the other carbon is capable of being similarly acted upon in the same way, the luminous point can thus be placed at any desired elevation, at whatever distance the operator may be from the regulator; and he can separately or simultaneously move both carbons as occasion requires.

As to the signals, there are two methods of proceeding. Either the light of the signalling apparatus may be extinguished by a commutator, or the lights may be hid by a screen electrically made to descend in front of the arcs. In the latter case the apparatus are fitted up with a special system of electro-magnets, by which the movement is easily effected. De Mersanne has fitted up several patterns, which may be applied to any other kind of regulator; the problem is not one of any difficulty.

The signalling apparatus just described has been made to work by hand; but the regulation of the light may obviously be automatically produced in a very simple way, by causing a mechanism connected with the light-producing current to act on the commutator already mentioned.

One small detail in the construction of the commutator is of some importance. It is a platinum wire which glows when the lamp itself is lighted, and is extinguished with the latter. The person sending the signals is therefore aware, although he may not see the lamp, when this latter is lighted.

Application to the Arts of War.—The extreme intensity of the electric light, and the ease with which it can at will be made to instantly appear and disappear at a distance, render it capable of important applications in military operations, either for signals, or as a means of illuminating at night a distant point to be observed, or to light up the work of the assailants in sieges. Martin de Brettes published, twenty years ago, an interesting paper on this subject, and this we have reproduced in the second edition of our *Exposé des applications de l'Électricité, tome III.*, page 258. We have here space for only a few extracts:

"Signals in the field or at a siege," says Martin de Brettes, "are chiefly intended for the transmission of orders or urgent despatches. It is therefore clear that the best system of luminous signals is that in which the light is most simply produced, is seen from the greatest distance, and has the greatest regularity in the appearance of the lights combined to produce the signs required in a telegraphic correspondence.

"As to the property possessed by the electric light of being seen at a considerable distance, its superiority for a good system of signals cannot be disputed. Nevertheless, rockets may in general, under ordinary circumstances, be advantageously employed on account of their simplicity, the ease with which they can be carried about and used. But when a powerful permanent luminous signal is required, the electric light will be of great help, and may prevent the use of a captive balloon in the field.

"Again, circumstances occur in war in which an illumination of a longer or shorter duration is required; for instance:

"To reconnoitre a fortification, the besieger requires a momentary light sufficient for his purpose, and not so prolonged as to attract the attention of the besieged.

"To direct the fire of a battery on a given point, that point must be lighted up long enough to allow a good aim to be taken.

"In order not to be taken by surprise by the opening of trenches, the besieged should continuously light up the ground where that operation is likely to be executed.

"The lighting up of a battle-field or of a breach at the time of the assault, requires also an illumination of an indefinite duration.

"Thus there may be required in war, either a momentary illumination, or one prolonged for perhaps the whole night. We have already seen that these two illuminations can be readily produced at will by the electric light, by closing or interrupting the voltaic circuit."

Martin afterwards explains the conditions for applying the electric light so as to obtain these results. At the time when his paper was written, however, the light could not be produced by electro-magnetic machines, and it would have been necessary to work with the cumbersome materials of a battery, which made the problem one of much greater difficulty. Now, thanks to the small dimensions of the magneto-electric machines, very considerable luminous intensities may be obtained, and this kind of application of the light becomes an easy matter. The magneto-electric—or, best of all for this purpose, the Gramme—machine, may be mounted to a portable engine, which can be as easily moved about to any required position as the cannons. The system used in France is driven by a Brotherhood three-cylinder machine. The electro-magnets of the Gramme machine are thin, flat, and very wide; the bobbin has two current collectors, and a commutator mounted on the armatures allows the machine to be joined up for tension or for quantity. This plan, as shown in Fig. 71, has been adopted by France, Russia, and Norway.

According to Fontaine, it was found, by experiments made at Mount Valérien with a machine thus arranged, that an observer, placed beside the apparatus, is able to see objects 6,600 metres distant, and to distinguish clearly details of construction at a distance of 5,200 metres. To obtain these results, the Gramme machine must have a power of 2,500 lamps, and the projector must concentrate the light by reflection and refraction, as in those projectors we have described for lighting ships at sea.

When the electro-magnets of the machine are joined up for quantity, it turns with a speed of 600 revolutions per minute, and expends 4 H.-P.; the light produced varies from 1,000 to 2,000 lamps. In the second case it makes 1,200 turns, employs 8 H.-P., and gives light equal to from 2,000 to 2,500 lamps. When the weather is clear, the machine is joined up for quantity, and the expenditure of steam is then small, the working easy, and the carbons are consumed slowly. When the weather is foggy and thick, the machine is arranged for tension, the expenditure of steam increases, the working requires rather more care, and the carbons are consumed quickly. With the Brotherhood motor the change of power is effected instantaneously.

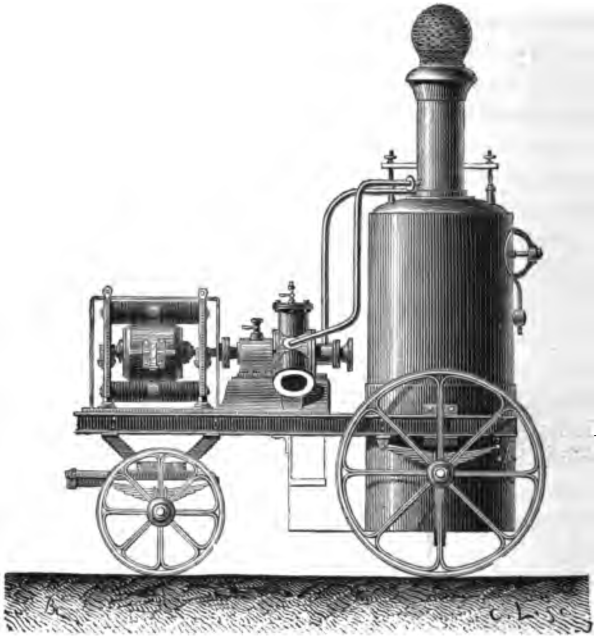


FIG. 71.

For war signalling, Gramme has fitted up a small machine which can be worked by a man's arm. This machine, worked by four men, gives a light equal to 50 Carcel lamps. The French Government has lately had it tried.

Experiments with machines arranged in nearly the same way were made in Berlin in 1875. The light produced was intense enough at a mile's distance to allow ordinary writing to be read. When a mirror placed in front of the regulator was inclined so as to reflect the rays upwards, a luminous track was thrown upon the clouds, and from a distance appeared like the tail of a comet, in which the signals made before the mirror showed themselves.

Mangin's projector is the one adopted in France for military operations, and it is in arrangement somewhat similar to that of Siemens', which we have shown in Fig. 70. It is mounted on a low light truck, by which it can easily be taken wherever required. This apparatus, described in detail in the *Mémorial de l'officier du génie* (Engineer Officer's notebook), is composed essentially of a concavo-convex glass mirror with spherical surfaces of different radii. The convex face is covered with silver, and reflects. This mirror, 90 centimetres in diameter, has the property of being free from spherical aberration, notwithstanding its diameter and its focal length being nearly equal.

Between the mirror and the luminous arc is a concavo-convex lens with its concavity towards the light. Its use is to collect upon the mirror a greater number of the rays, and thus increase the amplitude of the field of illumination.

The beam leaving the apparatus when the lamp is at the focus of the lens is exactly bounded by a circumference almost free from penumbra, and without other divergence than that due to the dimensions of the source of light, which divergence is about 2½ degrees. The light is uniformly distributed over the whole surface.

This apparatus also possesses the property of being made at will, either to light up a considerable space or to concentrate its intensity on one point, and this renders it extremely suitable for certain military operations. A simple displacement of the luminous point produced by a screw effects the change.

In some other experiments made with these apparatus at Toulon and at Cherbourg an unexpected fact was established, namely, that when the concentrated beam is projected upon a ship, the pilot has much difficulty to enter a port. This is a new means of defence.

It has been proposed to send signals from captive balloons. In this case the signal regulator of De Mersanne may be advantageously employed.

Lighting of Railway Trains.—The intense brilliance of the electric light, and the easy method of throwing it in any direction, have suggested in its employment for lighting railway trains running at night, and for announcing them at a greater distance were it only by the illumination of the sky at the place they are passing. Experiments made on the *Chemin de fer du Nord* have been perfectly successful, and seem to indicate that this plan of lighting will one day become general. In the meanwhile Girouard has invented the following system.

The electric generator, or Gramme machine, is fitted up on the tender, and is driven by a toothed wheel moved by an independent piston fixed on the lower part of the frame. One of Watt's governors controls the admission of the steam. A copper tube connected with a cock fixed on the engine is coupled to a pipe leading to the slide valve of the motor cylinder. In order to protect the magneto-electric apparatus from rain and dust, it is enclosed in a wooden casing, and only the cylinder remains outside. It will easily be seen that this arrangement is very solid, although independent of the engine. Its parts can be attended to by the person who usually cleans the engine.

In front of the locomotive there is firmly fixed a lantern containing an electric lamp provided with a powerful reflector, and in front of the lantern is placed, at an angle of

45 degrees, a semi-transparent platinized plate of glass. This glass is mounted in a frame so arranged that it can be turned a little to the right or left, while still inclined at the same angle. Further, a frame containing three coloured glasses, red, white, and green, is placed in front of the reflector, and serves at the same time to protect the lantern from wind and rain.

A jointed rod proceeds from the frame of the inclined glass, and another from the frame carrying the coloured glasses, and these rods are connected with two small levers within reach of the engine-driver. The lamp is connected with the magneto-electric machine by two cables, and when the current passes in the lamp the luminous rays are thrown forward by the reflector, but, as the glass is slightly platinized, only a portion of the beam proceeds straight forwards, whilst the other is projected upwards towards the sky in the form of a cone. By means of the first lever this cone can be turned obliquely either to the right or to the left, while the forward illumination still continues, and by means of the second lever the rays can be coloured either red or green. Now, by giving a certain meaning to each combination, a considerable number of signals may be formed. Besides this, although a train may be passing through a deep cutting or be hidden from sight by curves and inclines, or although the direct view of it may be intercepted by bridges or other objects, the beam projected vertically indicates its position at a great distance.

Application of the Electric Light to the Lighting of the Drifts in Mines, &c.—Several men of science, and among the rest De la Rive, Boussingault, and Louyet, have laid claim to having thrown out the first suggestion of the use of the electric light in mines. The idea originated, as seems to me to have been proved, with Louyet; but the application of it was certainly not made until 1845 by Boussingault.

Everybody knows of the dangers miners are exposed to when gas, issuing from the beds of coal, comes into contact with the flame of a lamp. A dreadful explosion takes place, and fires the whole drift. These sad accidents are called explosions of *fire-damp*. Now as the electric light is independent of a supply of air, for it can be produced in a vacuum, the danger of fire-damp will obviously be avoided, by enclosing each lamp in hermetically-sealed globes, placed in the drifts where the miners are working. It will, however, be necessary to exhaust these globes, lest the dilation by heat of the enclosed air should break them. There is then not the least danger to be feared, for the luminous points are thus completely separated from the external air.

In order to avoid the considerable cost of setting up the electric light, Dumas and Benoit conceived the idea of substituting the light of the inductive spark in a vacuum; they therefore arranged the vacuum tube spirally, and placed it in an outer tube, provided with copper fittings for suspending. The exhaustion is made on Morren's gas, in order to obtain a fine white light. I have spoken at length about this kind of illuminating tubes in my account of Ruhmkorff's induction apparatus (5th edition), and to this I refer the reader.

The electric light produced by the *Alliance* machines was successfully used in 1863 by Bazin for lighting the slate quarries of Angers. A machine with 4 discs was capable of lighting a gallery 60 metres long, by 50 metres wide and 40 metres high. The machine was near the opening of the shaft, and the electric current was transmitted by wires 150 metres long. In spite of the diminution of intensity occasioned by this great length of wire, the illumination proved so satisfactory that the workmen expressed their delight by loud applause. These advantageous results were confirmed on several different occasions, and it was found that the effective labour of the workmen was increased by a fifth or a sixth—a net advantage of 15 or 20 per cent. to add to the comfort of the workmen, which it was desirable to secure even at a high cost. There were, however, only two points of light. (See *Les Mondes*, *tome I.*, page 691, and *tome II.*, pp. 221 and 278).

The electric lighting of the slate quarries at Angers has lately been provided for in a permanent manner by Lorain. For this purpose a Gramme machine of the pattern described on page 75, and two Serrin regulators, have been used. The large subterranean gallery thus lighted up is no less than 100 metres in length, with a width varying from 15 to 50 metres, and a height of 60 metres. The whole of it—walls, vaulted roof, and floor—is black, yet in spite of the absence of reflection from its surfaces, it is illuminated almost as well as it would be in broad daylight under a clear sky, and with great satisfaction to the workmen and advantage to the Company.

A speed of 800 turns per minute would appear to be sufficient for obtaining a splendid light with the Gramme used, if the regulator had been placed near it; but on account of the depth of the quarry the regulator was about 350 metres from the source of electricity. In order to obtain a good light and a regular working of the apparatus, it was requisite to give the machines a mean and nearly constant velocity of 1,135 revolutions per minute. Conducting wires of a greater diameter are about to be used, and this will allow of such a reduction of the velocity that the electro magnets will not become heated beyond 50°.

The machines have been running simultaneously and continuously day and night since they were put up, eight months ago. With regard to duration and continuity, this experiment is the most conclusive that has hitherto been made with the Gramme machine, which has victoriously stood this severe test. (See the journal *La Lumière électrique* for 15th May, 1879.)

The employment of the electric light for the illumination of works carried on at night was one of the first useful applications of this method of lighting, and, dating from the works of the *Pont Notre-Dame*, where it was brought into use for the first time, it has always been employed whenever any important work had to be expeditiously performed. It has, for instance, been made use of in the works for the *Docks Napoléon*, in the rebuilding of the *Louvre*, &c., &c. In such applications the lantern is commonly set up at the top of a wooden post, and is furnished with a reflector for throwing the light downwards. It has also been proposed to apply the electric light in field labours in order to expedite harvest operations. Albaret, the head of a great firm of agricultural implement manufacturers at Liancourt, has lately made at Mornant and at Petit-Bourg, experiments that have proved successful. The apparatus (described in the journal *L'Électricité* of the 5th Sept., 1878) is composed of (1°) a portable steam-engine; (2°) a dynamo-electric machine of some kind or other; (3°) a post made of iron bars, serving to carry the lantern and the lamp, and fitted to the portable engine. The engine may, if it has sufficient power, be utilized to drive a thrashing machine. A windlass in front of the chimney enables the post to be raised or lowered.

Application to Lighting Railway Stations, Workshops, &c.—The electric lighting of large workshops and railway stations is now *un fait accompli*. Following Hermann-Lachapelle, who was one of the first to enter upon this course, a multitude of other manufacturers now use it with very great satisfaction. Fontaine's book tells us that Gramme machines now illuminate the establishments of Ducommun, at Mulhouse; of Sautter and Lemonnier, at Paris; of Menier, at Grenelle, Noisiel, and Roye; the spinning-mills of Dieu-Obry, at Daours; of Ricard *fils*, at Mauresa (Spain); of Buxeda, at Sabadell (Spain); of David, Trouillet, and Adhemar, at Épinal; of Bourcard (Doubs); of Horrocks and Miller, at Preston; the weaving-shops of Grégoire, at Crève-Cœur-le-Grand; of Manchon, at Rouen; of Brindle, at Preston; of Mottet and Baillard, at Rouen; of Isaac Holden, at Rheims; the workshops of Coron and Vignat, at Saint-Étienne; of Maës, at Clichy; of Descat-Leleu, at Lille; of Pulher and Sons, at Pesth; of Carel, at Ghent; the yards of Jeanne Deslandes, at Havre; the workshops of Mignon, Ronart, and Delinières at Montluçon; the quay of the canal between the Marne and the Rhine, at Sermaize; the goods station at La Chapelle, Paris; and also the different places undertaken by the Jablochkoff Company mentioned in pages 228-9.* The result has everywhere been satisfactory. Fontaine's work gives details on the fitting up of these systems of lighting. We shall here merely describe that of the station of the *Chemin du fer du Nord*, on account of the ingenious method by which a light is obtained not fatiguing to the eye, and capable of illuminating the various parts of the hall by nearly perpendicular rays, thus obviating the shadows thrown by packages, and throwing over them a flood of light like that of the torrid zone.

This method consists in arranging round the regulators, which are hung up at various points of the halls, a kind of reflector partly formed by the support of the lamp and partly by a sort of inverted ground-glass funnel, so placed that the luminous arc cannot be seen directly from any part of the hall. The light thus partially stopped is reflected towards the ceiling, as well as that which proceeds from the upper part of the arc; and as the ceiling is painted white, it is capable of forming in its turn an immense reflector, which sends down the luminous rays almost vertically, and thus prevents the very dark shadows which would be cast by the packages. By the adoption of this method, it has been found possible to reduce the number of men on the staff for night services, and the number of small articles lost has been much diminished. E. Reynier has improved this system by making the reflecting apparatus and the lantern which causes the regulator much easier to manage. In his arrangement the apparatus is moved like the suspenders in a dining-room. We have not space here to give the details of this interesting arrangement, but we shall, at a later period, publish a more complete description.

---

* Besides these establishments, Fontaine mentioned, in the beginning of 1877, a number of other workshops lighted in this way. Among the rest were the cannon foundry at Bourges; the workshops of Cail, those of the Mediterranean Iron Works Co. at Havre, those of Crespin and Marteau at Paris, of Beaudet at Argenteuil, Thomas and Powell at Rouen, Ackermann at Stockholm, Avondo at Milan, Quillacq at Anzin; those of Fives-Lille, of Tarbes, of Barcelona; the Midi Stations at Brussels; the workshops at Fourchambault; the foundries of Bességes and of Fumel; the dye-works of Guaydet at Roubaix, of Hannart at Wasquehal; the weaving shop of Baudot at Bar-le-Duc; the laundry of the Lyons hospitals, &c.

The Gramme Company has also fitted up for the shops of the *Louvre* a luminous ceiling, which has proved equally successful. The ceiling is formed in the first place of a large plate of ground unsilvered glass, which constitutes the base of a large hollow pyramid of tin-plate intended to act as the reflector; an electric light regulator suspended and balanced by a counterpoise is placed within this pyramid, so that the reflected rays may be thrown as uniformly as possible on the ground glass. A second reserve regulator can, moreover, be readily substituted for the first one when the carbons have to be renewed.

The light reflecting system, used at the goods station of the *Chemin du fer du Nord*, has been employed at Vienna to illuminate a skating rink 133 metres long. Two Gramme machines and two Serrin lamps, above which were hoisted large reflectors of elliptical curvature, were enough to light up the rink splendidly. This is the most successful of open air applications.

Splendid electrical illuminations have recently been provided at the picture exhibition in the Champs-Elysées at Paris, and at the exhibition of electric light apparatus at the Albert Hall, London. The former have been produced by Jablochkoff candles, the latter with these candles combined with Siemens' lamps. The results, although leaving room for some improvement as regards the steadiness and the appearance of the illuminated objects, have shown the immense resources this method of lighting places in our hands.

Besides the Châtelet Theatre in Paris, which has for several months been partially lighted by the Jablochkoff system, the Gaiety Theatre in London has been lighted throughout the winter by the electric light, the apparatus employed being Lontin's.

To dismiss the subject of electric illuminations, we may here state the results, as noted in the American newspapers, of the lighting of Cleveland Park, where the Brush system was used. According to these newspapers, this system of lighting must have been more economical than those tried in England and France in the proportion of 4 to 1. It is asserted that this illumination is supplied by twelve Brush lamps of the pattern described on page 178, excited by one of the same inventor's machines not requiring more than 11 H.-P. to drive it, and that each of these lamps has a luminous power of 2,000 candles, or 200 Carcel lamps. These 12 lamps are represented to have advantageously replaced the 100 gas-jets which had hitherto been used, and the amount of light given off is stated to have been about three times that produced by the gas.

We think this account is exaggerated, for if each Brush light represent 200 gas-jets, the 12 should be equal to 2,400 jets. Now, we see that the total illumination is only three times better than the original lighting, which was 100 jets; the Brush illumination would therefore represent only 300 gas-jets, or 25 for each electric lamp.

We must here mention, as important adoptions of the electric light, those recently made at the South Kensington Museum, and at the *Jardin d'Acclimatation* at Bordeaux. There the Werdermann system has been used, and apparently with much success.

Application of the Electric Light to Fishing.—It has not yet been decided whether the electric light plunged beneath the surface of the water, attracts fish or drives them away. According to some persons, it would be a means of making miraculous draughts, and Jobard, of Brussels, published in 1865 a very ingenious paper on this application; but we must unfortunately dispel the illusions which were formerly cherished. J. Duboscq has in fact constructed, to the order of an Anglo-French nabob, a large globe lamp for the electric light, with which experiments were made one fine summer evening on the *lac d'Enghien:* the waters were perfectly illuminated, but the fish, instead of coming towards the light, avoided it in alarm; not one was seen, so the apparatus has been useless. This discomfiture is described as above by l'Abbé Moigno; but we observe that his opinion was not very conclusive, for we read in the journal of *Les Mondes*, *t. XII.*, p. 46, *t. VI.*, p. 584, *and t. V.*, p. 374, articles on fishing by the electric light, in which he attaches more importance to the matter. In fact, he quotes an article stating that Fanshawe had been very successful in this way, catching by bait many whitings and mackerel. According to this amateur fisherman, the appearance of the sea during the experiment was splendid; the reflected light carried the greenish-blue colour of the water from the bottom to the summit of every wave. The sails and rigging of the vessel were also illuminated, and it seemed as if it were floating in a sea of gold. The silvery fish darted all around and constantly rose towards the surface of the illuminated water, presenting the appearance of brilliant jewels in a sea of azure and gold. It is true that in another article the author of the *Les Mondes* describes the experiments made at Dunkirk with a submarine lamp excited by currents from an *Alliance* machine, experiments which have left much uncertainty on the action of the light on fishes.

Electric lights have, however, been constructed for fishing, and Gervais has, according to the journal *Les Mondes* of the 30th March, 1865, a rather ingenious one, which is attached to a buoy, and can be let down to any required depth.

Application to Submarine Working.—Since diving-bells and various other apparatus for supporting respiration under water have made it possible to work at the bottom of the sea, several kinds of hydraulic work, and numerous recoveries of sunken vessels have been executed with ease. When the depth of the water which is to be entered is not great, daylight readily penetrates the liquid layer and affords sufficient light to the workers; but at a certain depth the light fails, and the submarine explorations, which must always precede the working, become impossible. No doubt, by fitting a lantern with apparatus for renewing the air, a light may be maintained as men's respiration is maintained; but this necessitates a supplementary pump and special apparatus to prevent the current of air from extinguishing the light. With the electric light the problem is solved in the simplest manner, and the extent of the space illuminated is much greater. The regulator with a globe, which we have already mentioned, may be used, or a special regulator to give the light directly in the water. However, as the light is in this last case much more difficult to control than when it is vacuo, the former method is to be preferred.

The experiments made at Dunkirk on fishing by the electric light have allowed the way in which the light behaves under water to be examined, and it has been found that magneto-electric machines, as well as the light they produce, are certainly applicable to submarine working. At a depth of 60 metres the light remained quite steady, and it illuminated a very large surface. The machine, moreover, was placed at more than 100 metres from the regulator. The surface of the glass in the lantern remained perfectly transparent, and the consumption of the carbons was less than in the open air.

Applications to the Projections on a Screen of Optical Experiments, Photographic Transparencies, &c.—There are many physical phenomena which require to be projected on a screen in order to be visible to a whole audience. There are certain of these (relating to the nature of light itself) which require an extremely intense light to show them. No doubt, with solar light and a heliostat, the problem may be immediately and cheaply solved. But more often than not, the sun is absent when he is required, and we are forced to forego those experiments which not only impart greater interest and attraction to a course of lectures, but which are much better understood and much better remembered when they have been strikingly presented to the eye. The electric light can be most successfully substituted for the sun in this kind of application, and Duboscq's regulators have, as we have seen, been arranged purposely for that object.

The apparatus for projecting the electric light consists of: 1st, an arrangement for steadying the light, so that the consumption of the two carbons does not displace the luminous point; 2nd, a closed lantern containing the regulator; 3rd, a plano-convex lens, for making parallel the divergent rays coming from the luminous point; 4th, of a system of optical apparatus, which we cannot here discuss without departing from the subject of this work.* We shall describe only the lantern, as that is a consequence of the electric regulator.

Duboscq's lantern is formed of a kind of bronzed copper box, which surrounds the upper part of the regulator. To economize space, the column of the regulator is enclosed in a sort of chimney in which the box terminates. To hermetically close the box, small shutters, moved by rackwork, close the top and bottom of the box at the same time that its door is closed, so that the openings made in the instrument for introducing the regulator are completely shut. The inside of the lantern is provided with a reflecting mirror and two supports, on which two other mirrors can be fitted, in order to throw the light on the lenses of a certain apparatus called the *polyorama*, adapted to the lantern for certain experiments. Finally, in the side of the lantern is a small bull's-eye, with a violet glass, by which the condition of the light is examined. In order easily to regulate the position of the luminous point, which in some experiments must be fixed in the most exact manner, the regulator is placed on a stand which can, by means of two screws, be moved in two rectangular directions (up-and-down and sideways).

---

* See my account of the method of projecting the principal phenomena of optics by means of Duboscq's apparatus.

The projections may be made at any distance; only they lose their brightness and clearness where the distance is out of proportion to the intensity of the light: 5 metres is commonly the most suitable distance for the light from a battery of fifty elements. We show in Fig. 72 an experiment of this kind.

The magic lantern gives, with the electric light and Levy's or Favre and Lachenal's transparent photographic views, effects so striking that a spectator would fancy he is transported to the very spot; and such a perfection in the views is now attained that the objects sometimes seem to stand out in relief, as in the effects of the stereoscope. This method of projection is now much used commercially, and, besides Duboscq's apparatus, which are applicable to every kind of optical experiment, there are those of Molténi, which are exclusively adapted for this kind of application.

Among the projection experiments that have been made by these apparatus, we may particularly mention that of the reading of microscopic despatches forwarded during the siege of Paris by carrier-pigeons; these despatches, each of which covered less than a square millimetre, were easily read before the multitude of those who were interested in receiving news from the provinces. Fig. 73 represents this application of the electric light.

The electric light has also been used for the photographing of places or objects not otherwise illuminated. In this way Levy has reproduced the pretty fountain under the staircase of the *Grand Opéra*, and certain English and American artists have succeeded in so truly reproducing the features and details of grottoes and dark caverns, that only by the shadows cast was it possible to distinguish them from places illuminated by daylight. Several photographers have desired to

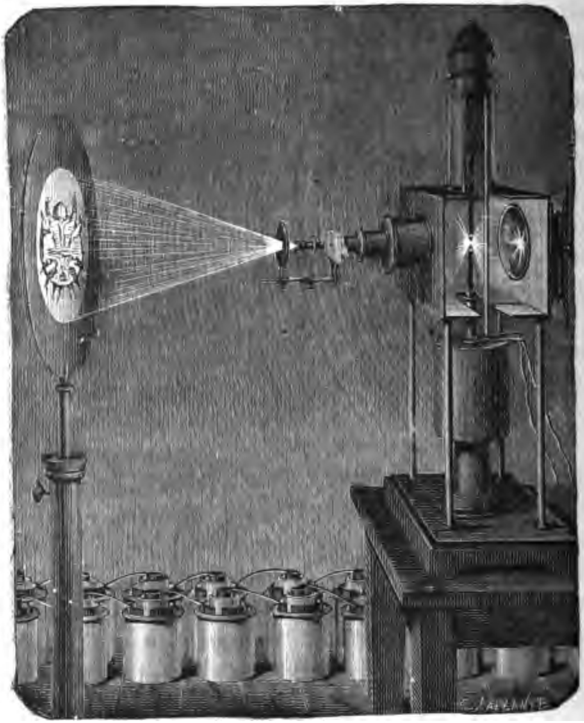


FIG. 72.

use this means for copying and printing, and Pierre Petit and Liebert have even lately fitted up a complete electrical arrangement for taking portraits in this way. We read in the Scientific Correspondence of the 14th January, 1879, the following news :—

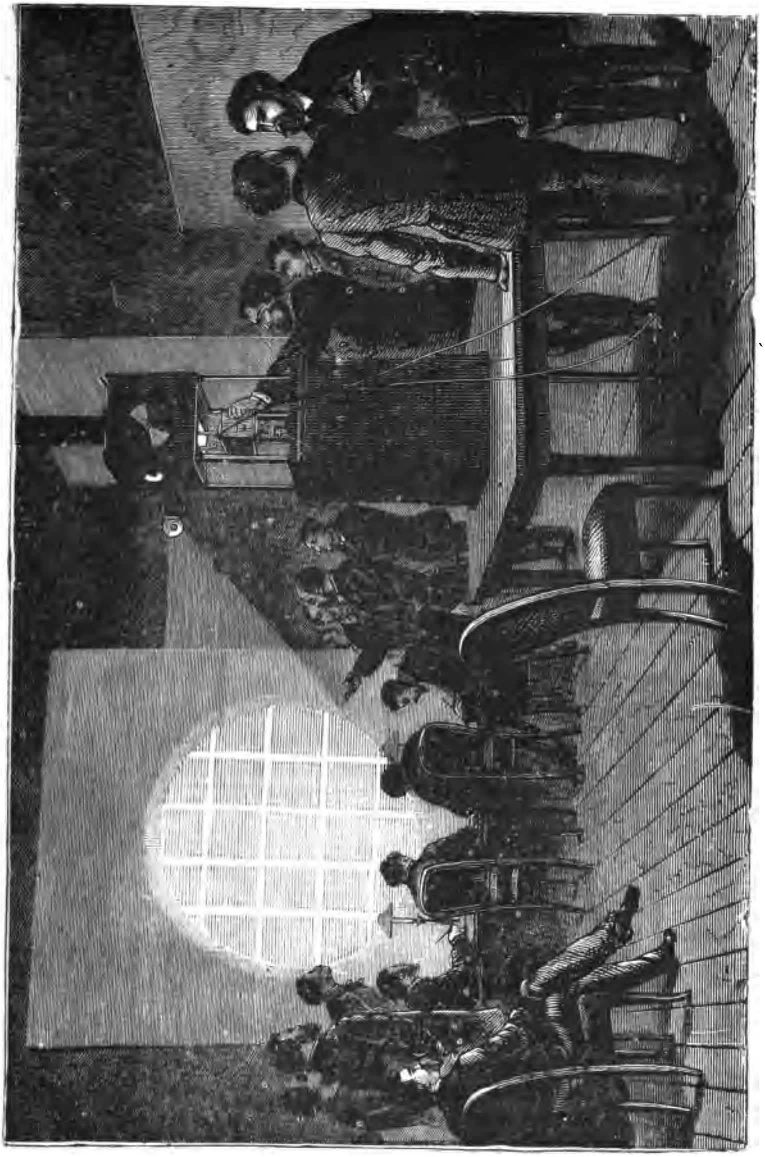


Fig. 73.

"A. Liebert, the well-known distinguished artist, last Saturday invited the press to his artistic and elegant mansion in the *Rue de Londres* to witness photographic experiments by means of the electric light. We use an ill-chosen word in saying experiments, for they were not experiments, but a real and practical application of the electric light to photography. The sun is no longer indispensable; I believe Liebert has even dispensed with his services entirely. By the new system the studio is always ready to receive sitters, at midnight as well as at noon, and the operations are carried on regularly and uninterruptedly.

"Liebert obtains these interesting results by means of a very simple arrangement. A hemisphere of two metres in diameter is hung from the ceiling, so as to present its concavity towards the sitter. This hemisphere carries two electric light carbons, of which one is fixed, while the other is made movable by a screw connected with its holder. The carbons are brought together at right angles to each other. It is, in fact, an ordinary regulator, with only the difference that there is no mechanism, the carbons being brought together by hand as required by their consumption. At each posing of the sitter the two carbons must be placed at the proper point. The duration of the sitting is so short that this cannot fail during the interval.

"The novelty and the improvement of the system consist in the circumstance of the light not falling directly upon the sitter. This light is first of all projected upon a screen, which in turn reflects it to the interior of the hemisphere, which is of dazzling whiteness, so that the luminous rays thus dispersed and divided surround the person whose portrait is to be taken. The illumination is splendid; the face is softly lighted, without any hard and exaggerated shadows. The sitter's eyes easily support the brilliancy of this light, and do not suffer from any unpleasant glare.

"A dozen portraits were taken between 11 o'clock and midnight with the greatest ease, and all were perfectly successful, to the great satisfaction of the guests so kindly invited by M. and Mme. Liebert.

"The electric light used for this purpose is produced by a Gramme machine, driven by a gas-engine of 4 horse-power at the rate of 900 turns per minute."

Public Trials of the Electric Light.—According to a claim advanced by Deleuil in the journal *Les Mondes* of the 26th November, 1863, it was his father who made the first experiment on the large scale with the electric light, and that in 1841 at the *Quai Conti, No.* 7. For this purpose he used a Bunsen battery of 100 cells, and produced the light between two carbons in an exhausted globe. Among the scientific men who were present at this experiment was Cagnard de la Tour, who was able to read a label in the crown of his hat at the base of the statue of Henri IV. Another experiment was made in 1842 by Deleuil *père*, on the *Place de la Concorde.* Nevertheless, it was Archereau who in the first instance most contributed to popularize the electric light, and I shall ever bear in mind that the experiments made by him every evening, either in the *Rue Rougemont* or in the *Boulevard Bonne-Nouvelle,* determined my taste towards electrical science. This excellent pioneer of science I have, therefore, to thank for starting me in the career I have ever since pursued.

Since these first public experiments many interesting trials of the electric light have been made, as at Rio Janeiro on the occasion of the anniversary of the independence of Brazil, frequently at London, and for two months the *Avenue de l'Impératrice* was lighted by means of two Lacassagne and Thiers lamps put up on the *Arc de Triomphe de l'Étoile.* Wonderful experiments were also made at Boston, in 1863, to celebrate the victories of the Federal armies (see the full account of these fêtes in *Les Mondes, tome II.*, page 165); at the ball given at Paris in honour of the Emperor of Russia, equally brilliant experiments were made under the direction of Serrin; they have also long been carried on at *Le Carrousel,* at the *Bois de Boulogne,* at the *Lac des Patineurs,* and in a multitude of other cases where people went to see the electric light as they would go to see fireworks. At the present time the novelty of all these effects has worn off, and we are getting so tired of them that they attract only a limited degree of attention. On the stage, however, this light produces its full effect, and the play of the *Pommes de Terre Malades*, in which it was used on the French stage for the first time, the operas of *Le Prophète*, *Moïse*, *Faust*, and *Hamlet*, and the ballets of *La Filleule des Fées*, *La Source*, &c., have shown what admirable resources this light has placed at the disposal of the scenic artist.

Application of the Electric Light to Theatrical Representations. — The most striking effects that the electric light has produced on the stage have been contrived by Duboscq. For this purpose he has arranged in the new Opera-House a room set apart for the necessary batteries and engines. Without stopping to describe the effect of the rising sun in *Le Prophète*, which everybody at once admired, and which was produced by a mere upward movement of the regulator—a movement skilfully disguised by a number of more or less transparent curtains; without speaking of the application of the voltaic arc for projecting a bright light on certain parts of the stage, in order to make groups or portions of the scenery stand out brilliantly, we may state that the intense rays of the electric light have served to reproduce upon the stage certain physical phenomena in their natural aspect, such as rainbows, flashes of lightning, moonlight, &c. This source of light is the only one which has proved intense enough to produce on the immense stage of the new Opera-House those effects of light and phantasmagoria which the public find so striking.

According to Saint-Edme, from whom we borrow these details, the rainbow was produced at the Opera-House for the first time by Duboscq, in 1860, in the revival of *Moïse*. The occasion of the appearance of the rainbow in the first act of that opera is well known. At first, bands of coloured paper in the curtain, representing the sky of Memphis, were illuminated by large oil-lamps simply. Afterwards came the electric light, but only the method of illumination was changed, and it was not until many attempts had been made by Duboscq that a real rainbow was obtained, in the following manner:—

"The electric apparatus supplying the arc," says Saint-Edme, "is placed on a stand of suitable height at 5 metres distance from the curtain, and perpendicularly to the canvas representing the sky. The whole optical apparatus is arranged and fixed in a blackened case, which diffuses no light externally. The first lenses give a beam, which afterwards encounters a screen cut out in the form of a bow. This beam is received by a double convex lens of very short focus, which serves the two purposes of increasing the curvature of the image, and of spreading it out. On leaving this last lens the rays traverse the prism, by which they are dispersed and made to produce the rainbow. The position of the prism is not a matter of indifference; its angle must be at the top of the incident beam, or otherwise the colours will not be displayed in the order in which they appeared in the rainbow. By this method the rainbow appears luminous even when the stage is fully lighted.

"It is no difficult matter to imitate peals of thunder in the theatre; the shops supply *tam-tams* and elastic sheet-iron for this purpose; but it is not so easy to make lightnings flash on the stage with anything like a natural effect. At first the phenomena was imitated by lighting a narrow zigzag cleft in the scene, with red fire from behind. With the progress of scenic art, it was necessary to do something better, and by the aid of science the source of light was found in the voltaic arc, which is identical in origin with the lighting itself. But what further had to be found, was some optical arrangement by which the luminous beam could be emitted and cut off at rapid intervals, while giving the zigzag movement characteristic of lighting. For this purpose Duboscq had recourse to a kind of magic mirror, in front of which the electric light was placed. This mirror was concave, and the luminous arc was situated at its focus. The upper carbon was fixed, but the lower carbon could at any required moment be drawn back, when the light would flash out. This could also be done by electro-magnetic attraction, and as the mirror was held in the hand it was possible, by shaking it and using the commutator, to obtain currents in various directions, by which the zigzags of flashes of lightning and their instantaneous apparition were imitated."

Very curious effects may also be produced by Colladon's fountain illuminated by the electric light, by reason of the complete illumination of the jets, and various colours they may be made to assume. But the greatest sensation produced by the application of science to the theatre, has been the apparition of spectres on the stage amongst the actors. The reader will recollect the famous apparitions in the piece called *Le Secret de Miss Aurore*, which drew so many people to the *Châtelet* theatre in 1863; and the performances of Robin and Cleverman are not so long past that one cannot recall the deep impressions produced by the spectres they raised and fought with.

The whole secret of this display consisted in a plate of unsilvered glass placed in front of the actors, and inclined at an angle of 45 degrees to the stage. This plate of glass reflected the images of living spectres, strongly illuminated by the electric light, who were placed in an opening below at the front part of the stage. These images were visible on all sides without intercepting the view of the objects, actors, or scenes on the other side of the glass. It was necessary to success, that the position of the persons representing the spectres should be so arranged that their images should appear vertical and seem to stand upon the floor, and also that their movements should accord with those of the actors on the stage; opening and closing the illuminating apparatus by means of a movable screen, would cause the appearance and disappearance of the spectral images.

PART VI.—CONCLUSION.

If all that has been said in the foregoing work be mentally reviewed, and its logical conclusions be sought for, the question of electric lighting may thus be stated:—

The peculiar character of the electric light resides in its concentrated power, by which an illumination equal to that from two to four thousand Carcel lamps may be given to a single point. This property may be extremely useful for certain purposes, particularly for lighthouses and ships, but it evidently is an inconvenience as regards public illumination, and for a long time methods have been sought by which this brilliancy may be divided between several lights, in order not only to diminish the glare, but to extend the light over a larger space. Unfortunately, the methods which have been tried for effecting this division have solved the problem only at the cost of a great loss of the intensity produced by a single light, But we shall see that by a well-known arrangement it may nevertheless be utilized under sufficiently favourable conditions.

It is certain that if the electric arc gives a light too intense to be directly borne by the eye, it must be moderated by diffusing globes, by which much light is absorbed and simply lost. This is the case with the Jablochkoff candles, the glass enamel globes of which absorb as much as 45 per cent. of the light. But if by any means the light could be so divided that these diffusing globes would be unnecessary, this loss would cease, and it might happen that with a suitable arrangement there would still be some advantage in using this system in spite of even a considerable loss of light compared with that produced by a single arc. In the first place, this mode of lighting does not involve, like others, a great heating of the surrounding atmosphere; and in the second place, there would be nothing to fear from the chances of explosions and fires, nor would the decorations of an apartment be spoiled. Besides, the white light does not change the natural hues of the illuminated objects, and this may be a great advantage for drapers' and other shops where the effects of colours have to be considered. Lastly, on account of the diminished risks, assurance companies will evidently be able to lower their rates.

With regard to expense, it may be that electric lighting will prove cheaper than gas, although the trials already made seem to show the contrary; but we must remember that these trials are not yet perfect, and we see already that since the erection of the Jablochkoff system in the *Avenue de l'Opéra*, the cost of each electric light, which was at first said to be five times that of gas, was lowered by one-half in the estimate given by the company to the city of Paris, and we think this might again be halved so as to bring the cost to only 40 centimes per hour for each light. It may be said, it is true, that the cost of gas for an equivalent light is only 27 centimes; but let us suppose that the globes, which absorb 45 per cent. of the light produced, stopped only 24 per cent., as Clémendot believes he can guarantee, the cost would fall below that of gas. These data, it must be understood, are merely approximative, and I quote the above figures only in order to show that it would not be impossible to produce the electric light at a cost within reach of practice. In any case the Company which works the Jablochkoff candles has rendered an immense service by showing the possibility of lighting of public thoroughfares by the electric light, which had before that been doubted. We have to thank the initiative taken by the Company, and the beautiful experiments it instituted, for electric lighting having become a question of the day, and in every country new researches have been prosecuted, which will sooner or later lead to the solution of the problem. Several towns in Europe and

America are about to be illuminated by this system, of which we believe we have not heard the last word.

It is already certain that a more complete study of the division of the light will lead to results more satisfactory than those already known.

In order that some idea may be formed of the improvements within our reach, it will suffice for me to say that, in the investigations hitherto made, the various elements that play an important part in the magnitude of the effect produced have not been sufficiently attended to. Thus, for example, a well-known relation between the resistance of the external circuit and that of the generator can greatly increase the proportion of the useful work. Nor should it be forgotten that the intensity of the light varies in proportion ever so much greater than that of the intensity of the electric current. It is already known that the calorific action produced by the current varies as the square of its intensity, but the resulting light varies in a still higher ratio; for, according to Preece, a platinum wire heated to 2,600° F. gives forty times as much light as when it is heated to 1,900° F. This explains why the division of the light is attended by so great a loss; since with each weakening of the current resulting from this division, there is a loss of light which may, under certain conditions, attain the eleventh power of the ratio of the diminution of the current.

All these considerations show that the solution of the lighting problem requires much further investigation before it becomes altogether practical; but we believe that no one of the questions belonging to it is insoluble, and that before long we shall witness at least a partial transformation in public illumination.

NOTES AND APPENDICES.

NOTE A.

ON THE INDUCTIVE ACTIONS IN THE NEW DYNAMO-ELECTRIC MACHINES.

THE inductive actions resulting from the relative movements of the inducing and induced circuits are seldom studied with exactitude, and on that account very inaccurate theories of several recently invented dynamo-electric machines have been put forward. The following series of experiments may serve to fix our ideas on the subject:—

Let us suppose that on a powerful straight magnet are wound several spires of an insulated wire, the ends of which are connected with a distant galvanometer, and let the coil so formed be capable of taking different positions on the magnet. If this coil is placed at the south pole of the magnet, and a soft iron armature is brought near that pole, a current will be obtained corresponding in duration with a magnetizing current, for it results from the increase of magnetic energy communicated to the bar by the presence of the armature. This current will give a deviation of 12 degrees to the right, and on withdrawing the armature we shall have a second deviation of 12 degrees to the left. Therefore, in the following experiments a deviation to the right will represent *inverse* currents, and a deviation to the left, *direct* currents.* Let us now see what will happen from the various movements given to the coil when it is passed from the poles towards the neutral line of the magnet, and from the neutral line towards the poles. This is what will be observed:—

---

* It should be observed that the direction of the currents due to the increase or diminution of magnetic intensity is always the same, whether

1°. When the coil is passed from the south pole towards the neutral line, a deviation of 22 degrees to the right will be obtained, and therefore an *inverse* current, or one of magnetization.

2°. On making the reverse movement a new current will be produced, and will cause a deviation of 25 degrees towards the left, and therefore the current will be *direct.*

3°. If, instead of passing the coil from the neutral line towards the south pole, the first movement is continued by bringing the coil from the neutral line towards the north pole, a current will be obtained in the direction opposite to that produced in the first half of the movement, and if the coil is stopped half-way a deviation of 12 degrees to the left will be obtained.

4°. On bringing the coil back from the last position

---

the currents are evoked at one or the other pole of the magnet, or at both together, and whatever may be the position of the coil on the magnet. But the currents produced will be the more energetic as the action takes place nearer to the coil. Thus, by placing the coil at the centre of the magnet on the neutral line, the current due to the increase of magnetization resulting from the approximation of an iron armature to one or other of the two poles will be inverse and of 2 degrees, and that which will result from the removal of the armature will be direct and of the same intensity. By acting simultaneously on the two poles and developing the armature, these currents will show themselves in the same direction, and will attain an intensity represented by 7 degrees. If the coil is placed at one of the poles, at the south pole for instance, the currents will be of 10 to 12 degrees, when the armature is brought near, or withdrawn from, the south pole; but they will be of only ½ degree when the north pole is acted upon, and but of 9 degrees when the armature acts upon the two poles simultaneously.

On placing the coil near the north pole, half-way between that pole and the neutral line, we shall have an inverse current when the armature approaches the poles; but it will be one of only 5 degrees when the north pole is acted upon, and one of only 2 degrees when the south pole is acted upon. It will become one of 9 degrees when the armature is made to act upon both poles at once, and the effects will of course be reversed when the armature is withdrawn instead of being brought near.

towards the neutral line, a fresh deviation of 10 degrees to the right will be obtained.

It follows from these experiments that the induced currents, caused by the movements of the coil along the magnet, will be the same as if the neutral line represented a *resultant of all the magnetic actions of the bar.* If this resultant were represented by a line through which the whole magnetic current were passing, there would follow from the approach of the movable coil to this line a current which, according to Lenz's law, would be *inverse;* and this is in fact precisely what takes place, since in bringing the coil back from the south pole, or from the north pole towards the neutral line, deviations to the right are obtained. Besides, it must follow from the same law, that on withdrawing the movable coil from that line, *direct* currents should be obtained, and this is found to be the case, since the deviations are to the left.

It will therefore be understood that, in accordance with these considerations, a small coil movable round a magnetized ring, setting out from the neutral line of one of the two semicircular magnets composing the ring, and moving towards the inducer by which the ring is polarized, must give a *direct* current, and this is precisely what is observed in the Gramme machine.

Let us now examine what occurs from the passage of the coil just mentioned, before the inducing pole itself, which I shall suppose to be the south pole of the preceding magnet; but this time, instead of taking the small coil, of which we spoke at first, we shall take a real bobbin of little thickness and capable of sliding along an iron rod, which acts on its magnetic core. In order to know the directions of the currents that we shall observe, we shall begin by examining the direction of the current produced when we bring near the south pole of the magnet the small bobbin, which we shall present by its anterior extremity, that is to say, by the extremity which in the following experiments goes first. Under these conditions we shall obtain a deviation to the right of

25 degrees, and when we withdraw the coil we shall obtain a deviation of 22 degrees to the left. As this experiment is the reproduction of Faraday's well-known one, we perceive that the deviations to the right will represent *inverse* currents, and that the deviations to the left will represent *direct* currents.

Now, if we take the coil in question, and cause it to pass from right to left tangentially before the south pole of the inducer, taking care to produce the movements in two parts, we shall observe :—

1°. That in the first half of the motion a current will be produced causing a galvanometric deviation of 8 degrees to the left, and in the second half another current of 5 degrees in the same direction.

2°. That in effecting the movement in the contrary direction, the current will be produced in the inverse direction.

It may therefore be concluded that the *currents resulting from the tangential movement of a coil before a magnetic pole* are produced under conditions altogether different from those which result from a movement effected in the direction of the axis of the magnet. These two movements are, in fact, produced not only in two perpendicular directions, but also under different conditions with regard to the manner in which the induction is produced in the various parts of the spiral. In the case of the tangential movement, the induction takes place only on one half of the circumference of the spires, and it acts from the two sides on a different end of the coil. It is not thus in the other case; the relative positions of the different parts of the coil remain in the same condition as regards the inducing pole, and it is only the position of the resultant that varies with regard to the direction of the motion.

It remains to find what occurs when the coil performing the movements just considered is subjected to the action of a magnetic core, influenced by the inducer, and in this case it suffices to cause the coil to pass along the iron rod of which we have spoken, while exposing the latter to the action of the inducing pole. On proceeding thus the following effects are observed:—

1°. At the first moment, when the inducing pole is being brought near the iron rod, but at a distance sufficient to allow the coil to pass between it and this pole, there is produced in the coil, placed on one side, an induced current which results from the magnetization of the rod, and gives a deviation of 39 degrees to the right. The deviations on this side correspond then with *inverse* currents.

2°. When the coil, placed as in the first series of experiments, is moved from right to left, it produces, from the moment it comes near the inducing pole, a current of 22 degrees to the left, which is, therefore, a *direct* current, and by continuing the movement beyond the inducing pole a new current is obtained in the same direction of 30 degrees to the left.

The effects produced by the passage of the coil before the inducer are therefore in the same direction with or without an iron rod, but are much more energetic with the iron rod.*

---

* The effects produced in this experiment should be carefully noted, for they prove that the magnetic actions are not so simple as is generally supposed. In fact, the results which we have just pointed out cannot be established unless the movable coil is placed on the part of the induced iron rod, intermediate between the inducing pole and its free extremities. Beyond this intermediate part the currents produced are in the opposite direction, which proves that in this case the iron rod has become a true magnet regularly constituted. Of course, if the rod is exposed to the inducing pole at one of its extremities, the magnet has only two poles and one neutral line; but if it is exposed to this inducer at its centre, it forms a magnet with a *consequent point*, and has therefore two neutral lines. If, however, the iron rod, instead of being at a distance from the inducing pole, is in contact with it, the effects are quite different. The currents produced by the movement of the coil towards the magnet are always inverse, and those which result from its withdrawal are direct. This shows that the resultant of the magnetic forces is then concentrated at the inducing pole, which plays the part of a neutral line, as if the two magnetic pieces formed but one. This effect is always produced, on which side soever of the magnetic pole the iron rod is applied. If, however, under these conditions, the rod is separated from the magnet by a magnetically isolating substance, the effects without being

It may therefore be said that the currents produced in consequence of the displacement of the coils of a Gramme ring, in relation to the two resultants corresponding with the two neutral lines, are in the same direction as those evoked by the passage of the spires of the coils before the inducing pole in each half of the ring.

In order to study the effects resulting from the *polar inversions*, the experiment may be arranged as follows:—on one of the extremities of the iron rod provided with the induction coil mentioned above, a permanent magnet is made to slide perpendicularly to its axis. In this way the rod undergoes successive inversions of its polarities, and it is seen that not only is there produced by this a current more powerful than the magnetization and demagnetization currents which result from the action of the pole of the magnet, but also that this current is not momentary, and appears to increase in energy until the inversion of the poles is complete. The direction of this current varies according to the direction of the movement of the magnetized bar, and if it is compared with that which results from the magnetization or demagnetization of the magnetic core under the influence of one or other of the poles of the magnetized bar, it is observed that it is *exactly of the same direction as the demagnetization current caused by the pole that has first acted;* it is therefore in the same direction as the magnetization current of the second pole; and as, in the movement performed by the magnet, the magnetic core is demagnetized, in order to be again magnetized in the con-

exactly those we have analysed with the tangential movement of the coil, somewhat resemble them, and the difference depends upon the currents, resulting from the movements of the coil with regard to the magnets, being in the direction contrary to those which result from the magnetization of the rod, and giving rise to a rather feeble differential current, which shows that the last action preponderates. On the other hand, the currents produced from the middle of the rod to its free extremity, being no longer opposed by the direct action of the magnet, possess all their energy. (See my paper on this kind of actions in the *Comptes Rendus* for the 24th February, 1879.)

trary way, the two currents which result from these two consecutive actions are in the same direction, and consequently supply a single current during the whole movement of the magnet. Again, the movement in the opposite direction of the magnet, having for its effect at the beginning a demagnetization in the direction opposite to that produced in the first case, the retrograde current resulting from the retrograde movement must be in a direction the reverse of that of the first.

If we now return to the effects produced by our magnet, acting on our coils moving perpendicularly to their axes, it will be understood from the preceding that displacement of the magnetic polarity of the core must immediately be produced by the inducing magnet having for its effect the inversion of the contrary polarity of this core before and behind the points successively influenced, it must follow that the different parts of the core of the coils will successively constitute a series of magnets with inverted poles, analagous to those the effects of which we have already analysed, and which are able to produce those currents in the same direction, whose presence we have proved. These currents will change in direction according as the coils move from right to left, or from left to right. (See my article on the electrical actions in operation in light-producing machines, in the journal *La Lumière Électrique* of the 1st November, 1879.)

NOTE B.

ON THE DUTY OF GRAMME MACHINES ACCORDING TO THE RESISTANCE OF THE EXTERNAL CIRCUIT.

WE reproduce below an interesting paper of Hospitalier's, which shows the importance of the remark made at the conclusion of this work.

Dynamo-electric machines, considered as a source of electricity, cannot, by reason of the numerous conditions of their action, be classed with other electric sources, such as liquid batteries or thermo-electric batteries, and therefore, thanks to the kind co-operation of Robert Gray, the engineer of the *Indiarubber Works Co.*, we undertook at Silvertown, in the month of July, 1879, a series of experiments to establish, apart from all theoretical considerations, the electric elements of dynamo-electric machines placed under certain conditions of action.

Our experiments had reference to Gramme machines of the A pattern, called the workshop pattern (represented on page 75 of this volume.) We must mention that similar experiments had been already made in France by Mascart and Angot (*Journal de Physique*, 1878), and in England by Hopkinson (*Institution of Mechanical Engineers*). The former were undertaken more particularly from a theoretical point of view, from which we cannot here regard them; the latter relates to Siemens' machines, and it is a similar investigation that we desire to have made in France on the machines which are here most in use.

Dynamo-electric machines are set up to work at a given speed, which it is convenient to maintain in order to produce from these machines all they can yield without damaging their parts or the solidity of their construction. We suppose, then, that the speed of rotation is constant, and we refer the electric elements to a normal velocity of 1,000 turns per minute. When the register indicates a greater or less velocity it is always easy to reduce it to this standard, for it is found by experiment that, other things being equal, the electromotive force is proportional to the number of revolutions of the machine even for variations reaching to 300 turns a minute.

We were particularly desirous of experimentally explaining the variations of the electric elements of the Gramme machines, by causing the external resistance to vary from 10 ohms to an external resistance of nothing.

Internal Resistance of the Machine.—On testing by the method of Wheatstone's bridge, the resistances of the machine experimented with were found to be:—

	ohms.
Total resistance of the machine before working	1·185
Resistance of the coil when warm, after having been working some time in short circuit	0·75
Resistance of the electro-magnets under the same conditions ...	0·72
Total resistance of the machine when *warm*	1·47

These figures show that the *internal resistance* of the machine varies within very narrow limits, and that these variations are due to the heating of the wire, the resistance of which increases with the temperature.

Electro-motive Force.—Curve I. of the diagram, given in Fig. 74, shows the variation of the electro-motive force when the external resistance increases. The total resistances are referred to the axis of the abscissæ, on a scale of $\frac{7}{10}$ths of a centimetre per *ohm;* the electro-motive forces are referred to the ordinates on a scale of $\frac{7}{10}$ths of a millimetre per *volt.* When the total resistance is more than four times the internal resistance, it will be seen that the electro-motive force is nearly constant and very feeble. This is due to the fact that the induction on the coil is produced only by the residual magnetism of the electro-magnets. Then this electro-motive force increases very rapidly between 6 ohms and 4 ohms of total resistance, and it reaches a value of 107 volts, varying then very little. This is caused by the electro-magnets being magnetized to saturation; the magnetic field remains constant, and as besides the speed of the induced system is constant, the electro-motive force, which is proportional to these two quantities, can vary only by the heating of the wire.

Intensity of the Current.—The intensity of the current, expressed in *webers,* is represented by the curve II. of the diagram on a scale of $\frac{7}{10}$ths of a millimetre per *weber.*

It will be seen that this intensity, at first very feeble, increases afterwards in a nearly regular manner for total resistances varying between twice and four times the total resistance of the machine. These intensities have been calculated by the formula

$$Q = \frac{E}{R}$$

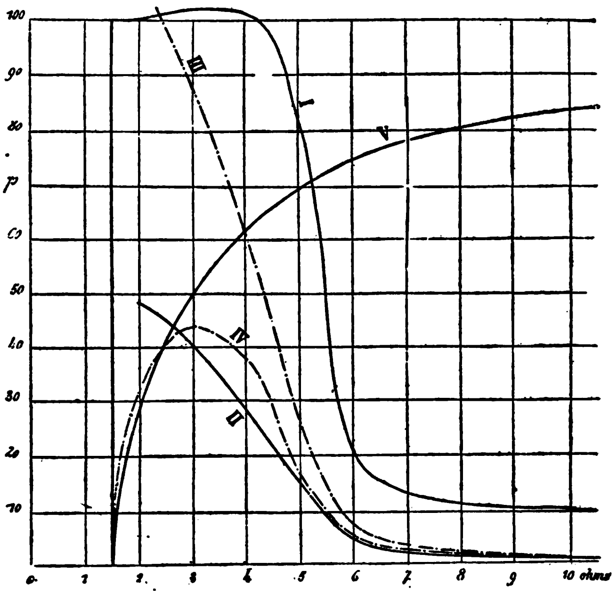


FIG. 74.

in which Q is the intensity in webers, E the electro-motive force in volts, R the total resistance in ohms.

Work transformed into Electricity.—The figures we have found are referred to the unit of time, the second. The value of the work transformed into electricity is expressed by Joule's formula, $W = 10\, Q^2 R$, in which Q and R have the same meaning as before, and W is the work in *meg-ergs*. In order to reduce to French units or kilogrammetres we must know that the kilogrammetre equals 98·1 *meg-ergs.*

Curve III. of the diagram shows that the work transformed into electricity, which is very small when the total resistance exceeds 6 ohms, increases afterwards rapidly and regularly as the resistance diminishes. The scale of curves III. and IV. is $\frac{7}{10}$ths of a millimetre for 2 kilogrammetres.

Utilizable Work in the External Circuit.—The current produced by a magneto-electric machine is divided into two parts: the internal work which heats the wire of the coil and the electro magnets, and which cannot be utilized, and the available work produced in the external circuit, and which may be employed either to heat a wire, as in our experiments, or to produce different effects.

The utilizable work, represented by curve IV. in the diagram, after having been very small, increases as the total resistance diminishes. It reaches its maximum when the external resistance is equal to the internal resistance of the machine, and afterwards diminishes to nothing when the machine is arranged in short circuit. In this case the whole of the work supplied by the motor is transformed into internal work, the machine becomes greatly heated, the brushes burn, and the insulation of the wire may even be damaged.

Duty.—Duty in its general sense is the ratio between the work expended and the work utilized. If only the work transformed into electricity is taken into account, as we shall do here, by neglecting the passive resistances and the friction of the parts, the duty is the ratio between the total work transformed into electricity (curve III.), and the work utilizable in the external circuit (curve IV). This ratio, always less than I., is represented by curve V. in the diagram. It will be seen that this ratio increases with the resistance, and tends towards I. for an infinite resistance, in which case there is no longer any current. This assertion seems, in contradiction to that which has often been made, that the duty is maximum when the external resistance is equal to the internal resistance. There is in this an error in the words which must be rectified.

It is not the *duty* that is maximum in this last case, for it is only 50 per cent., but *the utilizable work in the external circuit.* The largest quantity, therefore, of utilizable electricity will be obtained from a given machine by making the external resistance equal to the internal resistance, but the *highest electrical duty* will be obtained by making the external resistance equal to 5 or 6 times the internal resistance. Under these conditions the machine will supply very little electricity, but the greatest part of it will be utilized on the external circuit. In practice, it is preferred to lose on the duty, and to cause the machine to produce the most that it can furnish at its normal velocity, by placing it under the conditions of maximum utilizable work, a maximum which is attained when the external circuit is equal to the internal resistance, certain corrections being made, which, according to the experiments of Jamin, Roger, and Le Roux, must be introduced into the value of the internal resistance.

In one experiment, the machine turning with a velocity of 1,000 revolutions per minute, with an external resistance of 2·7 ohms, or 1·8 times the internal resistance, a current was produced of 25·5 webers intensity, with an electro-motive force of 107 volts. The total work transformed into electricity was 273 kilogrammetres, or 3·64 horse-power; the utilizable work was 179 kilogrammetres, or 2·38 horse-power.

In this case the duty reached 65 per cent. By taking into account friction, passive resistances, &c., the value of which might reach 1 horse-power, the utilizable work is only about 50 per cent. of the work really used up by the machine.

Experiments made under various conditions of resistance on different machines manufactured at Silvertown gave similar results.

Tension and Quantity Machines.—If, on a given dynamo-electric machine, we expend a certain quantity of work W, the expression of this work transformed into electricity may be put into this form:—$W = Q E$. Now this may be done in these machines in two ways.

By making Q very great and E very small, the machine, having then little tension and supplying a large quantity of current, takes the name of a *quantity machine.*

Q may also be made very small and E very great; the machine, having little quantity and a large electro-motive force, takes the name of a *tension machine.*

The former class should work with an external circuit of small resistance; the latter, on the contrary, requires a considerable external resistance to satisfy the relations which should exist between the external and internal circuits in order to obtain the maximum utilizable effect.

In conclusion, we give a table showing the different values assumed by the electric elements of a machine, according as it is constructed to supply a so-called quantity current, or a so-called tension current.

Elements of the working of Gramme machines, determined by experiments made at Silvertown, July, 1879.

Electric Elements.	Quantity Machine.	Tension Machine.
Number of turns per minute	797	967
Internal resistance in ohms	1·20	4·58
External resistance	1·14	4·00
Total resistance of the circuit	2·34	8·58
Intensity of the current in webers...	29·67	17·51
Electro-motive force in volts	81·58	158·50
Work expended in kilogrammetres	243	277

It will be seen that, according to this table, for the same quantity of work expended, the electric elements, resistance, intensity, and electro-motive force are notably different.

It is possible to construct intermediate machines by suitably adjusting the lengths and thicknesses of the wire on the coils; but the figures we have just given show within what limits the Gramme machines used for the electric light are comprised.

NOTE C.

THE CRITERIA OF THE ELECTRIC LIGHT.

WE here extract the following passages from a paper by W. H. Preece, which we find in the *Telegraphic Journal* of the 15th February, 1879 :—

" Heat and light are identical in character, though different in degree; and whenever solid matter is raised to a very high temperature it becomes luminous. The amount of light is dependent upon the height of this temperature; and it is a very remarkable fact that all solid bodies become self-luminous at the same temperature. This was determined by Daniell to be 980° (F.), by Wedgwood 947°, by Draper 977°; so that we may approximately assume the temperature at which bodies begin to show a dull light to be 1,000° (F.) The intensity of light, however, increases in a greater ratio than the temperature. For instance, platinum at 2,600° (F.) emits forty times more light than at 1,900°. Bodies when raised to incandescence pass through all stages of the spectrum: as the temperature increases so does the refrangibility of the rays of light. Thus, when a body is at a temperature of—

250° F., it may be called warm.
500° „ „ hot.
1,000° we have the red rays.
1,200° „ „ orange rays.
1,300° „ „ yellow rays.
1,500° „ „ blue rays.
1,700° „ „ indigo rays.
2,000° „ „ violet rays.

So that any body raised to a temperature above 2,000° will give us all the rays of the sun. Inversely, the spectroscope may thus be enabled to tell us the temperature of the different lights, and it is, perhaps, because some lights do not exceed 1,300° that we lose all those rays beyond the yellow.

"Tyndall has shown that the visible rays of an incandescent wire bear to the invisible rays a much smaller proportion than in the arc, and it is generally assumed that for the same current the arc will give at least 2½ times greater light than an incandescent wire. Tyndall's figures are as follows:—

	Visible Rays.		Invisible Rays.
Gas	1	to	24
Incandescent wire ...	1	to	23
The arc	1	to	9

"The requirements of a good electric lamp are first, intense brilliancy; secondly, great steadiness; thirdly, duration. The Serrin lamp has the first kind of excellence; all those lamps based on incandescence excel in the second respect; the Wallace Farmer light is the only one that attains the third point. The Rapieff is perhaps that form which, up to the present, most nearly combines the three requisites, but in reality no lamp has yet been introduced which fulfils all these requirements.

"The objections to the use of the electric light are:—

1°. The deep shadows it throws.

2°. The indifferent carbon that has hitherto been manufactured for the purpose, which leads to unpleasant sounds, to great variation in the intensity of the light, and to waste.

3°. The difficulty in distributing the light itself. It is so intense, and confined to so small a space, that it does not lend itself to distribution like the gas flame, which occupies a considerable space.

4°. The unsteadiness of the light due to variations in the speed of the engine employed in driving the dynamo machine. There is another cause of variation in the electric arc, and that is the variation in the resistance of the arc itself, for it has been clearly demonstrated by experiments both in America and in England, that the resistance of the arc varies as the resistances in circuit vary. The following table will show this:—

Current in Webers.	Light in Candles.	Resistance of Arc. Ohms.
10	440	2·77
16·5	705	1·25
21·5	900	1·67
30·12	1,230	·54

"The light in the arc varies directly as the current, and not as the square of the current, as generally assumed.

"Now, in the case of light raised by incandescence, the light will increase as the square of the current. It follows that if in the one case—viz., the arc—the light increases as the current only, and in the other case—viz., incandescence —it increases as the square of the current, a point is reached when the light produced by incandescence will equal that produced by the arc. The difficulty in reaching that point is the difficulty of obtaining a conductor with a sufficiently high point of fusion to resist the effect of powerful currents. Iridium is the only metal that is known to do this, and iridium is too scarce and too dear to be used for the purpose.

"The multiplication of the light by Gramme's machine upon the Thames Embankment must not be taken as the solution of the problem of the subdivision of the light. Theory shows unmistakably that to produce the greatest effect we must have only one machine to produce one light. We know from absolute measurements that such a machine can be made to produce a light of 14,880 candles, and it is possible to produce 1,254 candles per horse-power. But the moment that we attempt to multiply the number of lights in circuit this power diminishes, so that we have on the Embankment lamps giving us a light of scarcely more than 100 candles. The light of the Rapieff lamp in the *Times* office appears to be about 600 candle-power, and the Wallace light is equal to 800 candle-power. In these two instances six lights are used in one circuit, but we have not here the subdivision of the light; we have, on the contrary, the multiplication of the light, produced by the increased speed of the engine due to the insertion of additional lamps. It is, however, easily shown that if in a circuit where the electro-motive force is constant we insert additional lamps, then when these lamps are joined up in one circuit, *i.e.*, in series, the light varies inversely as the square of the number of lamps in circuit, and when joined up, as in the multiple arc, the light diminishes as the cube of the number inserted. Hence the subdivision of the light is an absolute *ignis fatuus*. In the first place no machine has yet been produced which is competent or capable to light over 20 lamps; secondly, no conductor is known but copper that is capable of conveying the current required to light these lamps, and copper is an expensive material; thirdly, no electric light has yet been produced combining all the criteria of a good light."

We consider this conclusion somewhat premature, and we must confess that on this point we do not quite agree with the learned English electrician.

NOTE D.

ON A NEW ARRANGEMENT OF THE WERDERMANN LAMP.

The new arrangement of the Werdermann lamp, mentioned on page 209, consists in the addition to the arrangement shown in Fig. 56 of a brake acting on the lateral contact, and put in operation under the influence of the end contact, which is for this purpose adapted to the extremity of a lever attached to the jointed guide that brings the brake into action. So long as the pressure exerted by the movable carbon on the end contact is uniform, the brake does not act, but the moment this pressure begins to diminish or increase, either on account of nodosities in the carbon, or from other causes, the brake is loosened or tightened, and thus the carbon is allowed to advance more easily or less easily.

This arrangement of the end contact at the extremity of a jointed lever enabled the lamp to be automatically re-lighted in case it went out. For this purpose it was sufficient to place a contact below the jointed lever. When the latter is no longer kept up by the movable carbon, it falls upon the contact spring, and sends the current into the supplementary lamp.

NOTE E.

ON EDISON'S NEW DISCOVERY.

The new metal discovered by Edison, mentioned on page 215, is simply platinum freed *from the bubbles of gas enclosed in its pores by being several times heated in a vacuum for prolonged periods.* Under these conditions the metal becomes much harder than in its ordinary state, and less fusible.

Edison states that he has succeeded in obtaining a wire of this kind, giving with a radiating surface of $\frac{1}{32}$ of an inch, a light of 8 candles, which would, with the ordinary wires of commerce, have been only 1 candle. "I can therefore," he says, "by increasing the calorific capacity of platinum, use wires of very small radiating surface, and considerably reduce the electric energy necessary for the production of a light of 1 candle. *I have, in fact, succeeded in obtaining in this way* 8 *luminous centres, each giving a perfectly fixed light of* 18 *candles, and yielding a total light of* 138 *candles, using for the purpose only* 30,000 *foot-lbs., that is to say, less than* 1 *horse-power of steam.*"

TRANSLATOR'S APPENDIX.—No. 1.

ENGLISH EQUIVALENTS OF THE FRENCH DENOMINATIONS USED IN THIS VOLUME.

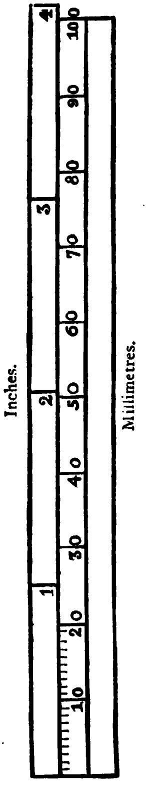


FIG. 75.

MEASURES OF LENGTH.

1 kilometre = 1000 metres = 0·6214 *mile* = 1093·6 *yards*.

1 metre = 1·0936 *yards* = 3·2809 *feet* = 39·37 *inches*.

1 decimetre = 0·1 metre = 10 centimetres = 100 millimetres = 3·937 *inches*.

1 centimetre = 0·01 metre = 0·1 decimetre = 10 millimetres = 0·3937 *inches*.

1 millimetre = ·001 metre = ·01 decimetre = 0·1 centimetre = ·03937 *inches*.

MEASURES OF SURFACE.

1 square metre = 1·196 *square yards* = 10·7698 *square feet*.

1 square millimetre = 0·00155 *square inch*.

MEASURES OF VOLUME.

1 litre = 1 cubic decimetre = 1000 cubic centimetres = 61·02709 *cubic inches* = 0·22017 *gallon* = 0·88066 *quart* = 1·76133 *pints*.

1 cubic centimetre (cc) = ·001 litre = 0·06103 *cubic inch*.

WEIGHTS.

1 kilogramme = 1000 grammes = 2·20462 *pounds avoirdupois*.

1 gramme = 15·43235 *grains* = 0·035274 *oz. avoirdupois*.

1 decigramme = 0·1 gramme.

1 centigramme = 0·01 gramme.

1 milligramme = 0·001 gramme.

WORK.

1 kilogrammetre = 7·233 *foot-lbs.*

THERMOMETRIC SCALES.

To convert centigrade degrees into Fahrenheit degrees multiply by $\frac{9}{5}$ or 1·8, and add 32 to the result.

MONEY.

1 franc = 100 centimes = 9·6 *pence.*
25 francs = £1 *sterling.*

TRANSLATOR'S APPENDIX.—No. 2.

RECENT INVENTIONS.

Since the publication of the original edition of this work, the inventors of electrical apparatus have not been idle. Patents without end have been, and continue to be, granted almost daily for alleged improvements in current generators, and for new forms of electric lamps. But none of these involves any principle which has not been already illustrated in the course of this work, nor does it yet appear that anyone is destined to supersede such forms of apparatus as are described in the text. Nevertheless, there are some quite recent developments of certain forms of apparatus that greatly affect the problem of electric lighting, and these may here be very briefly described.

Incandescent Lamps.—Incandescent lamps of extremely simple construction have been lately brought out by several inventors. These are all identical in principle, consisting of a slender filament of carbon enclosed in a vacuous vessel. They differ in such particulars as the dimensions of the carbon filament, the material from which it is prepared, the method of attaching its extremities to the current conductors, and the manner in which the vacuous vessels are exhausted and sealed. Such lamps will, without damage, bear a certain maximum of current for a more or less prolonged period, the amount of light depending, of course, upon their electrical resistance and the energy of the current. In operation, their average endurance, or "life," has been stated to be, under favourable circumstances, about 1,000 hours. The question of the subdivision of the electric light presents no difficulties with these lamps, and they solve the problem of the application of the light to domestic purposes.

Swan's Lamp.—The inventor of this lamp has discovered a method of preparing from cotton thread very attenuated filaments of carbon of the tenacity requisite for their sufficiently prolonged stability and endurance when in use. These extremely thin carbons are perfectly homogeneous throughout, and are so far from becoming damaged by use that the effect is to a certain extent an increase of their solidity and elasticity. The arrangement of the lamp, which is shown on Fig. 76, is extremely simple. The filament of carbon, bent round so as to form a spirally circular loop of about one-fifth of an inch in diameter, is enclosed in a glass bulb about two inches in diameter. The extremities of the filament are connected in an ingenious manner to two platinum wires, which pass outwards and either form two small loops, or terminate in binding screws, for connecting with the circuit. These platinum wires are fused into the bulb, and are supported by a piece of glass, which descends internally for a certain distance. The bulb is hermetically sealed, after having been completely exhausted by means of a Sprengel pump. The light yielded by these lamps is mild and steady, with an intensity depending, of course, on the current of electricity sent.

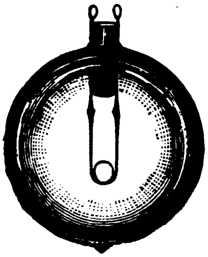


FIG. 76.

through them, but which may be safely carried as high as 20 candles. It is stated that 1 horse-power of force absorbed suffices to maintain 10 of these lamps. At the Exhibition of Electrical Apparatus at Paris in 1881, the Swan lamp received the gold medal as being the best system in its class.

Maxim's Lamp.—The carbons for this lamp are prepared from cartridge paper, and the vacuous bulbs contain a residual atmosphere of a hydro-carbon instead of air. It is claimed that by this the durability of the filament is increased, and the irregularities of the resistance at various points become equalized. This form of loop preferred by the inventor has four parallel vertical portions, nearly like a capital M. The resistance of this lamp is stated to be more than twice that of Swan's lamp. The light given out may be carried to 50 candles.

Edison's Lamp and Fox-Lane's Lamp.—Edison prepares his carbon from a filament of bamboo, while Fox-Lane makes use of a string of flax. Both make a single loop of the carbon, which is bent into a horse-shoe form. The resistance of Edison's lamp is about the same as that of Maxim's, while the resistance of the Fox-Lane lamp is less than that of the Swan.

The Faure Secondary Battery.—Planté's polarization battery, which was invented about 1859, has been mentioned in the text (page 15). This battery was formed by the action of the current from a primary battery on plates of lead immersed in diluted sulphuric acid. The nature of the polarizing action itself is explained on page 9. Faure also uses thin plates of lead for the elements of his cell, but instead of forming lead oxide by electrolysis, he coats one of the plates with a film of red oxide of lead, and this is separated from the other plate by a layer of felt. The Faure cells, or "accumulators," as they have been called, are made of a large size, and according to Sir W. Thompson, one of these cells, weighing 75 kilogrammes, "can store and give out again energy to the extent of an hour's work of one horse-power." The Faure cell may be charged by a voltaic battery or by any generator or dynamo-electric machine giving a direct current. The light of incandescent lamps worked by the Faure accumulator is perfectly steady, being absolutely free from those fluctuations which may usually be detected in the action of the dynamo-electric machines. Its great use for the electric light consists not only in its supplying the means of carrying a store of electricity about, but in affording a *regulator* for the lamps. In fact these might remain lighted for hours, even if the electric supply from the engine were interrupted. A train lighted up with incandescent electric lamps, worked by Faure's accumulators, has been running continuously for some months between London and Brighton, without any failure of the light once occurring. This invention imparts to electric illumination as great a degree of *readiness and certainty in working* as has been claimed for gas-lighting.

THE END.

DALZIEL BROTHERS, CAMDEN PRESS, LONDON, N W.

POPULAR WORKS ON SCIENCE

PUBLISHED BY

GEORGE ROUTLEDGE & SONS.

A Popular History of Science. By Robert Routledge, B.Sc. (Lond.), and F.C.S., Author of "Discoveries and Inventions of the Nineteenth Century." With many Original Illustrations and Portraits, and Sixteen Full-page Plates. Crown 8vo, cloth, 12*s*. 6*d*.

Discoveries and Inventions of the Nineteenth Century. By Robert Routledge, B.Sc. and F.C.S. With many Illustrations, and a Coloured Plate, 10*s*. 6*d*.

Science in Sport made Philosophy in Earnest. By Robert Routledge. Post 8vo, cloth, gilt edges, 5*s*.

The Boys' Book of Science. Including the Successful Performance of Scientific Experiments. 470 Engravings. By Professor Pepper, late of the Polytechnic. Cloth, gilt edges, 7*s*. 6*d*.

The Book of Metals. Including Personal Narratives of Visits to Coal, Lead, Copper, and Tin Mines; with a large number of interesting Experiments. 300 Illustrations. By Professor Pepper, late of the Polytechnic. Post 8vo, cloth, gilt edges, 6*s*.

The Microscope: Its History, Construction, and Application. Being a Familiar Introduction to the Use of the Instrument, and the Study of Microscopical Science. By Jabez Hogg, F.L.S., F.R.M.S. With upwards of 500 Engravings and Coloured Illustrations by Tuffen West. New Edition, crown 8vo, cloth, 7*s*. 6*d*.

The Common Objects of the Microscope. By the Rev. J. G. Wood. With Twelve Pages of Plates by Tuffen West, embracing upwards of 400 Objects. The Illustrations printed in Colours. Fcap 8vo, 3*s*. 6*d*., cloth, gilt edges.

⁂ A Cheap Edition, with Plain Plates, 1*s*, fancy boards.

The Orbs of Heaven; or, The Planetary and Stellar Worlds. A Popular Exposition of the great Discoveries and Theories of Modern Astronomy. By O. M. Mitchell. With numerous Illustrations. Crown 8vo, 2*s.* 6*d.*

Popular Astronomy; or, The Sun, Planet, Satellites, and Comets. With Illustrations of their Telescopic Appearance. By O. M. Mitchell. 2*s.* 6*d.*

The Story of the Peasant-Boy Philosopher. Founded on the Early Life of Ferguson, the Astronomer. By Henry Mayhew. Illustrated. Cloth gilt, 3*s.* 6*d.*

The Wonders of Science; or, The Story of Young Humphrey Davy, the Cornish Apothecary's Boy, who taught Himself Natural Philosophy. By Henry Mayhew. Illustrated. Cloth gilt, 3*s.* 6*d.*

The Book of Trades, and the Tools used in Them. By One of the Authors of "England's Workshops." With numerous Illustrations. Small 4to, cloth, gilt edges, 3*s.* 6*d.*

Wonderful Inventions, from the Mariner's Compass to the Electric Telegraph Cable. By John Timbs. New Edition, with additions. Crown 8vo, cloth, 5*s.*

A Manual of Fret-Cutting and Wood-Carving. By Sir Thomas Seaton, K.C.B. Crown 8vo, cloth, 2*s.* 6*d.*

The Laws of Contrast of Colours, and their Application to the Arts. New Edition, with an important Section on Army Clothing. By M. E. Chevreul. Translated by John Spanton. With Coloured Illustrations. Crown 8vo, cloth, 3*s.* 6*d.*

Geology for the Million. By Margaret Plues. Edited by Edward Wood, F.G.S. With 80 Illustrations. Fcap., picture boards, 1*s.*

Scientific Amusements. Edited by Professor Pepper. 100 Woodcuts. 1*s.*, boards; 1*s.* 6*d.*, cloth gilt.

Electric Lighting. Translated from the French of Le Comte Th. Du Moncel by Robert Routledge, B.Sc. (Lond.), F.C.S., Author of "Discoveries and Inventions of the Nineteenth Century," "A Popular History of Science," etc. With 76 Illustrations. Crown 8vo, cloth, 2*s.* 6*d.*

RETURN TO the circulation desk of any
University of California Library
or to the
NORTHERN REGIONAL LIBRARY FACILITY
Bldg. 400, Richmond Field Station
University of California
Richmond, CA 94804-4698

ALL BOOKS MAY BE RECALLED AFTER 7 DAYS

- 2-month loans may be renewed by calling (510)642-6753
- 1-year loans may be recharged by bringing books to NRLF
- Renewals and recharges may be made 4 days prior to due date

DUE AS STAMPED BELOW

DEC 14 2004

DD20 6M 9-03

FORM NO. DD6, 60m, 1/83 BERKELEY, CA 94720